US012150792B2

(12) United States Patent
Mason et al.

(10) Patent No.: US 12,150,792 B2
(45) Date of Patent: Nov. 26, 2024

(54) **AUGMENTED REALITY PLACEMENT OF GONIOMETER OR OTHER SENSORS**

(71) Applicant: **ROM TECHNOLOGIES, INC.**, Brookfield, CT (US)

(72) Inventors: **Steven Mason**, Brookfield, CT (US); **Daniel Posnack**, Brookfield, CT (US); **Peter Arn**, Brookfield, CT (US); **Wendy Para**, Brookfield, CT (US); **S. Adam Hacking**, Brookfield, CT (US); **Micheal Mueller**, Brookfield, CT (US); **Joseph Guaneri**, Brookfield, CT (US); **Jonathan Greene**, Brookfield, CT (US)

(73) Assignee: **ROM Technologies, Inc.**, Brookfield, CT (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 818 days.

(21) Appl. No.: **17/148,047**

(22) Filed: **Jan. 13, 2021**

(65) **Prior Publication Data**

US 2021/0128080 A1 May 6, 2021

Related U.S. Application Data

(63) Continuation-in-part of application No. 17/021,895, filed on Sep. 15, 2020, now Pat. No. 11,071,597.
(Continued)

(51) **Int. Cl.**
A61B 5/00 (2006.01)
G06T 11/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***A61B 5/7465*** (2013.01); ***A61B 5/684*** (2013.01); ***A61B 5/744*** (2013.01); ***G06T 11/00*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC A61B 2017/00203; A61B 2017/00207; A61B 2090/365; A61B 2090/372;
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,822,032 A 4/1989 Whitmore et al.
4,860,763 A 8/1989 Schminke
(Continued)

FOREIGN PATENT DOCUMENTS

CA 2698078 A1 3/2010
CA 3193419 A1 3/2022
(Continued)

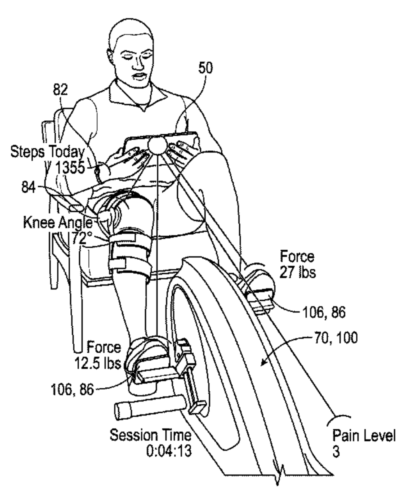
OTHER PUBLICATIONS

International Search Report and Written Opinion for PCT/US2023/014137, dated Jun. 9, 2023, 13 pages.
(Continued)

Primary Examiner — George Manuel
(74) *Attorney, Agent, or Firm* — Dickinson Wright PLLC; Stephen A. Mason; Jonathan H. Harder

(57) **ABSTRACT**

Systems and methods for positioning one or more sensors on a user. The system has user sensors, apparatus sensors, and treatment sensors. A processing device, executing computer readable instructions stored in a memory, cause the processing device to: generate an enhanced environment representative of an environment; receive apparatus data representative of a location of the apparatus in the environment; generate an apparatus avatar in the enhanced environment; receive user data representative of a location of the user in the environment; generate a user avatar in the enhanced environment; receive treatment data representative of one or more locations of the treatment sensors in the environment; generate, treatment sensor avatars in the enhanced environment; calculate a treatment location for each treatment
(Continued)



sensor, wherein the treatment location is associated with an anatomical structure of a user; and generate instruction data representing an instruction for positioning the treatment sensors at the treatment location.

30 Claims, 11 Drawing Sheets

Related U.S. Application Data

(60) Provisional application No. 62/910,232, filed on Oct. 3, 2019.

(51) **Int. Cl.**
G16H 20/30 (2018.01)
G16H 40/67 (2018.01)
G16H 80/00 (2018.01)
A61B 5/107 (2006.01)
A61B 5/22 (2006.01)
A61B 90/00 (2016.01)

(52) **U.S. Cl.**
CPC ***G16H 20/30*** (2018.01); ***G16H 40/67*** (2018.01); ***G16H 80/00*** (2018.01); *A61B 5/1071* (2013.01); *A61B 5/222* (2013.01); *A61B 2090/365* (2016.02)

(58) **Field of Classification Search**
CPC A61B 34/10; A61B 34/25; A61B 5/1071; A61B 5/222; A61B 5/684; A61B 5/744; A61B 5/7465; G06T 11/00; G16H 20/30; G16H 40/63; G16H 40/67; G16H 50/50; G16H 80/00
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,932,650	A	6/1990	Bingham et al.
5,137,501	A	8/1992	Mertesdorf
5,240,417	A	8/1993	Smithson et al.
5,256,117	A	10/1993	Potts et al.
5,284,131	A	2/1994	Gray
5,318,487	A	6/1994	Golen
5,356,356	A	10/1994	Hildebrandt
D359,777	S	6/1995	Hildebrandt
5,429,140	A	7/1995	Burdea et al.
5,738,636	A	4/1998	Saringer et al.
6,007,459	A	12/1999	Burgess
D421,075	S	2/2000	Hildebrandt
6,110,130	A	8/2000	Kramer
6,162,189	A	12/2000	Girone et al.
6,182,029	B1	1/2001	Friedman
6,267,735	B1	7/2001	Blanchard et al.
6,273,863	B1	8/2001	Avni et al.
6,413,190	B1	7/2002	Wood et al.
6,436,058	B1	8/2002	Krahner et al.
6,450,923	B1	9/2002	Vatti
6,491,649	B1	12/2002	Ombrellaro
6,514,085	B2	2/2003	Slattery et al.
6,535,861	B1	3/2003	OConnor et al.
6,601,016	B1	7/2003	Brown et al.
6,602,191	B2	8/2003	Quy
6,613,000	B1	9/2003	Reinkensmeyer et al.
6,626,800	B1	9/2003	Casler
6,626,805	B1	9/2003	Lightbody
6,640,122	B2	10/2003	Manoli
6,652,425	B1	11/2003	Martin et al.
6,890,312	B1	5/2005	Priester et al.
6,902,513	B1	6/2005	McClure
7,058,453	B2	6/2006	Nelson et al.
7,063,643	B2	6/2006	Arai
7,156,665	B1	1/2007	OConnor et al.
7,156,780	B1	1/2007	Fuchs et al.
7,169,085	B1	1/2007	Killin et al.
7,209,886	B2	4/2007	Kimmel
7,226,394	B2	6/2007	Johnson
RE39,904	E	10/2007	Lee
7,507,188	B2	3/2009	Nurre
7,594,879	B2	9/2009	Johnson
7,628,730	B1	12/2009	Watterson et al.
D610,635	S	2/2010	Hildebrandt
7,778,851	B2	8/2010	Schoenberg et al.
7,809,601	B2	10/2010	Shaya et al.
7,815,551	B2	10/2010	Merli
7,833,135	B2	11/2010	Radow et al.
7,837,472	B1	11/2010	Elsmore et al.
7,955,219	B2	6/2011	Birrell et al.
7,969,315	B1	6/2011	Ross et al.
7,974,689	B2	7/2011	Volpe et al.
7,988,599	B2	8/2011	Ainsworth et al.
8,012,107	B2	9/2011	Einav et al.
8,021,270	B2	9/2011	D'Eredita
8,038,578	B2	10/2011	Olrik et al.
8,079,937	B2	12/2011	Bedell et al.
8,113,991	B2	2/2012	Kutliroff
8,177,732	B2	5/2012	Einav et al.
8,287,434	B2	10/2012	Zavadsky et al.
8,298,123	B2	10/2012	Hickman
8,371,990	B2	2/2013	Shea
8,419,593	B2	4/2013	Ainsworth et al.
8,465,398	B2	6/2013	Lee et al.
8,506,458	B2	8/2013	Dugan
8,515,777	B1	8/2013	Rajasenan
8,540,515	B2	9/2013	Williams et al.
8,540,516	B2	9/2013	Williams et al.
8,556,778	B1	10/2013	Dugan
8,607,465	B1	12/2013	Edwards
8,613,689	B2	12/2013	Dyer et al.
8,672,812	B2	3/2014	Dugan
8,751,264	B2	6/2014	Beraja et al.
8,784,273	B2	7/2014	Dugan
8,818,496	B2	8/2014	Dziubinski et al.
8,823,448	B1	9/2014	Shen
8,845,493	B2	9/2014	Watterson et al.
8,849,681	B2	9/2014	Hargrove et al.
8,864,628	B2	10/2014	Boyette et al.
8,893,287	B2	11/2014	Gjonej et al.
8,911,327	B1	12/2014	Boyette
8,979,711	B2	3/2015	Dugan
9,004,598	B2	4/2015	Weber
9,167,281	B2	10/2015	Petrov et al.
9,248,071	B1	2/2016	Benda et al.
9,272,185	B2	3/2016	Dugan
9,283,434	B1	3/2016	Wu
9,311,789	B1	4/2016	Gwin
9,367,668	B2	6/2016	Flynt et al.
9,409,054	B2	8/2016	Dugan
9,443,205	B2	9/2016	Wall
9,474,935	B2	10/2016	Abbondanza et al.
9,481,428	B2	11/2016	Gros et al.
9,514,277	B2	12/2016	Hassing et al.
9,566,472	B2	2/2017	Dugan
9,579,056	B2	2/2017	Rosenbek et al.
9,629,558	B2	4/2017	Yuen et al.
9,640,057	B1	5/2017	Ross
9,707,147	B2	7/2017	Levital et al.
D794,142	S	8/2017	Zhou
9,717,947	B2	8/2017	Lin
9,737,761	B1	8/2017	Govindarajan
9,757,612	B2	9/2017	Weber
9,782,621	B2	10/2017	Chiang et al.
9,802,076	B2	10/2017	Murray et al.
9,802,081	B2	10/2017	Ridgel et al.
9,813,239	B2	11/2017	Chee et al.
9,827,445	B2	11/2017	Marcos et al.
9,849,337	B2	12/2017	Roman et al.
9,868,028	B2	1/2018	Shin
9,872,087	B2	1/2018	DelloStritto et al.
9,872,637	B2	1/2018	Kording et al.
9,914,053	B2	3/2018	Dugan

(56) **References Cited**

U.S. PATENT DOCUMENTS

9,919,198	B2	3/2018	Romeo et al.
9,937,382	B2	4/2018	Dugan
9,939,784	B1	4/2018	Berardinelli
9,977,587	B2	5/2018	Mountain
9,993,181	B2	6/2018	Ross
10,004,946	B2	6/2018	Ross
D826,349	S	8/2018	Oblamski
10,055,550	B2	8/2018	Goetz
10,058,473	B2	8/2018	Oshima et al.
10,074,148	B2	9/2018	Cashman et al.
10,089,443	B2	10/2018	Miller et al.
10,111,643	B2	10/2018	Shulhauser et al.
10,130,298	B2	11/2018	Mokaya et al.
10,130,311	B1	11/2018	De Sapio et al.
10,137,328	B2	11/2018	Baudhuin
10,143,395	B2	12/2018	Chakravarthy et al.
10,155,134	B2	12/2018	Dugan
10,159,872	B2	12/2018	Sasaki et al.
10,173,094	B2	1/2019	Gomberg et al.
10,173,095	B2	1/2019	Gomberg et al.
10,173,096	B2	1/2019	Gomberg et al.
10,173,097	B2	1/2019	Gomberg et al.
10,198,928	B1	2/2019	Ross et al.
10,226,663	B2	3/2019	Gomberg et al.
10,231,664	B2	3/2019	Ganesh
10,244,990	B2	4/2019	Hu et al.
10,258,823	B2	4/2019	Cole
10,325,070	B2	6/2019	Beale et al.
10,327,697	B1	6/2019	Stein et al.
10,369,021	B2	8/2019	Zoss et al.
10,380,866	B1	8/2019	Ross et al.
10,413,222	B1	9/2019	Kayyali
10,413,238	B1	9/2019	Cooper
10,424,033	B2	9/2019	Romeo
10,430,552	B2	10/2019	Mihai
D866,957	S	11/2019	Ross et al.
10,468,131	B2	11/2019	Macoviak et al.
10,475,323	B1	11/2019	Ross
10,475,537	B2	11/2019	Purdie et al.
10,492,977	B2	12/2019	Kapure et al.
10,507,358	B2	12/2019	Kinnunen et al.
10,542,914	B2	1/2020	Forth et al.
10,546,467	B1	1/2020	Luciano, Jr. et al.
10,569,122	B2	2/2020	Johnson
10,572,626	B2	2/2020	Balram
10,576,331	B2	3/2020	Kuo
10,581,896	B2	3/2020	Nachenberg
10,625,114	B2	4/2020	Ercanbrack
10,646,746	B1	5/2020	Gomberg et al.
10,660,534	B2	5/2020	Lee et al.
10,678,890	B2	6/2020	Bitran et al.
10,685,092	B2	6/2020	Paparella et al.
10,777,200	B2	9/2020	Will et al.
D899,605	S	10/2020	Ross et al.
10,792,495	B2	10/2020	Izvorski et al.
10,814,170	B2	10/2020	Wang et al.
10,857,426	B1	12/2020	Neumann
10,867,695	B2	12/2020	Neagle
10,874,905	B2	12/2020	Belson et al.
D907,143	S	1/2021	Ach et al.
10,881,911	B2	1/2021	Kwon et al.
10,918,332	B2	2/2021	Belson et al.
10,931,643	B1	2/2021	Neumann
10,987,176	B2	4/2021	Poltaretskyi et al.
10,991,463	B2	4/2021	Kutzko et al.
11,000,735	B2	5/2021	Orady et al.
11,045,709	B2	6/2021	Putnam
11,065,170	B2	7/2021	Yang et al.
11,065,527	B2	7/2021	Putnam
11,069,436	B2	7/2021	Mason et al.
11,071,597	B2	7/2021	Posnack et al.
11,075,000	B2	7/2021	Mason et al.
D928,635	S	8/2021	Hacking et al.
11,087,865	B2	8/2021	Mason et al.
11,094,400	B2	8/2021	Riley et al.
11,101,028	B2	8/2021	Mason et al.
11,107,591	B1	8/2021	Mason
11,139,060	B2	10/2021	Mason et al.
11,185,735	B2	11/2021	Arn et al.
11,185,738	B1	11/2021	McKirdy et al.
D939,096	S	12/2021	Lee
D939,644	S	12/2021	Ach et al.
D940,797	S	1/2022	Ach et al.
D940,891	S	1/2022	Lee
11,229,727	B2	1/2022	Tatonetti
11,265,234	B2	3/2022	Guaneri et al.
11,270,795	B2	3/2022	Mason et al.
11,272,879	B2	3/2022	Wiedenhoefer et al.
11,278,766	B2	3/2022	Lee
11,282,599	B2	3/2022	Mason et al.
11,282,604	B2	3/2022	Mason et al.
11,282,608	B2	3/2022	Mason et al.
11,284,797	B2	3/2022	Mason et al.
D948,639	S	4/2022	Ach et al.
11,295,848	B2	4/2022	Mason et al.
11,298,284	B2	4/2022	Bayerlein
11,309,085	B2	4/2022	Mason et al.
11,317,975	B2	5/2022	Mason et al.
11,325,005	B2	5/2022	Mason et al.
11,328,807	B2	5/2022	Mason et al.
11,337,648	B2	5/2022	Mason
11,347,829	B1	5/2022	Sclar et al.
11,348,683	B2	5/2022	Guaneri et al.
11,376,470	B2	7/2022	Weldemariam
11,404,150	B2	8/2022	Guaneri et al.
11,410,768	B2	8/2022	Mason et al.
11,422,841	B2	8/2022	Jeong
11,437,137	B1	9/2022	Harris
11,495,355	B2	11/2022	McNutt et al.
11,508,258	B2	11/2022	Nakashima et al.
11,508,482	B2	11/2022	Mason et al.
11,515,021	B2	11/2022	Mason
11,515,028	B2	11/2022	Mason
11,524,210	B2	12/2022	Kim et al.
11,527,326	B2	12/2022	McNair et al.
11,532,402	B2	12/2022	Farley et al.
11,534,654	B2	12/2022	Silcock et al.
D976,339	S	1/2023	Li
11,541,274	B2	1/2023	Hacking
11,621,067	B1	4/2023	Nolan
11,636,944	B2	4/2023	Hanrahan et al.
11,654,327	B2	5/2023	Phillips et al.
11,663,673	B2	5/2023	Pyles
11,701,548	B2	7/2023	Posnack et al.
12,057,210	B2	8/2024	Akinola et al.
2001/0044573	A1	11/2001	Manoli
2002/0010596	A1	1/2002	Matory
2002/0072452	A1	6/2002	Torkelson
2002/0143279	A1	10/2002	Porter et al.
2002/0160883	A1	10/2002	Dugan
2002/0183599	A1	12/2002	Castellanos
2003/0013072	A1	1/2003	Thomas
2003/0036683	A1	2/2003	Kehr et al.
2003/0064860	A1	4/2003	Yamashita et al.
2003/0064863	A1	4/2003	Chen
2003/0083596	A1	5/2003	Kramer et al.
2003/0109814	A1	6/2003	Rummerfield
2003/0181832	A1	9/2003	Carnahan et al.
2004/0102931	A1	5/2004	Ellis et al.
2004/0147969	A1	7/2004	Mann et al.
2004/0197727	A1	10/2004	Sachdeva et al.
2004/0204959	A1	10/2004	Moreano et al.
2005/0043153	A1	2/2005	Krietzman
2005/0049122	A1	3/2005	Vallone et al.
2005/0115561	A1	6/2005	Stahmann
2005/0143641	A1	6/2005	Tashiro
2006/0046905	A1	3/2006	Doody, Jr. et al.
2006/0058648	A1	3/2006	Meier
2006/0064136	A1	3/2006	Wang
2006/0064329	A1	3/2006	Abolfathi et al.
2006/0129432	A1	6/2006	Choi et al.
2006/0199700	A1	9/2006	LaStayo et al.
2007/0042868	A1	2/2007	Fisher et al.
2007/0118389	A1	5/2007	Shipon

(56) **References Cited**

U.S. PATENT DOCUMENTS

2007/0137307 A1 6/2007 Gruben et al.
2007/0173392 A1 7/2007 Stanford
2007/0184414 A1 8/2007 Perez
2007/0194939 A1 8/2007 Alvarez et al.
2007/0219059 A1 9/2007 Schwartz
2007/0271065 A1 11/2007 Gupta et al.
2007/0287597 A1 12/2007 Cameron
2008/0021834 A1 1/2008 Holla et al.
2008/0077619 A1 3/2008 Gilley et al.
2008/0082356 A1 4/2008 Friedlander et al.
2008/0096726 A1 4/2008 Riley et al.
2008/0153592 A1 6/2008 James-Herbert
2008/0161733 A1 7/2008 Einav et al.
2008/0183500 A1 7/2008 Banigan
2008/0281633 A1 11/2008 Burdea et al.
2008/0300914 A1 12/2008 Karkanias et al.
2009/0011907 A1 1/2009 Radow et al.
2009/0058635 A1 3/2009 LaLonde et al.
2009/0070138 A1 3/2009 Langheier et al.
2009/0270227 A1 10/2009 Ashby et al.
2009/0287503 A1 11/2009 Angell et al.
2009/0299766 A1 12/2009 Friedlander et al.
2010/0048358 A1 2/2010 Tchao et al.
2010/0076786 A1 3/2010 Dalton et al.
2010/0121160 A1 5/2010 Stark et al.
2010/0173747 A1 7/2010 Chen et al.
2010/0216168 A1 8/2010 Heinzman et al.
2010/0234184 A1 9/2010 Le Page et al.
2010/0248899 A1 9/2010 Bedell et al.
2010/0262052 A1 10/2010 Lunau et al.
2010/0268304 A1 10/2010 Matos
2010/0298102 A1 11/2010 Bosecker et al.
2010/0326207 A1 12/2010 Topel
2011/0010188 A1 1/2011 Yoshikawa et al.
2011/0047108 A1 2/2011 Chakrabarty et al.
2011/0119212 A1 5/2011 De Bruin et al.
2011/0172059 A1 7/2011 Watterson et al.
2011/0195819 A1 8/2011 Shaw et al.
2011/0218814 A1 9/2011 Coats
2011/0275483 A1 11/2011 Dugan
2011/0306846 A1 12/2011 Osorio
2012/0041771 A1 2/2012 Cosentino et al.
2012/0065987 A1 3/2012 Farooq et al.
2012/0116258 A1 5/2012 Lee
2012/0130197 A1 5/2012 Kugler et al.
2012/0183939 A1 7/2012 Aragones et al.
2012/0190502 A1 7/2012 Paulus et al.
2012/0232438 A1 9/2012 Cataldi et al.
2012/0259648 A1 10/2012 Mallon et al.
2012/0259649 A1 10/2012 Mallon et al.
2012/0278759 A1 11/2012 Curl et al.
2012/0295240 A1 11/2012 Walker et al.
2012/0296455 A1 11/2012 Ohnemus et al.
2012/0310667 A1 12/2012 Altman et al.
2013/0108594 A1 5/2013 Martin-Rendon et al.
2013/0110545 A1 5/2013 Smallwood
2013/0123071 A1 5/2013 Rhea
2013/0123667 A1 5/2013 Komatireddy et al.
2013/0137550 A1 5/2013 Skinner et al.
2013/0137552 A1 5/2013 Kemp et al.
2013/0178334 A1 7/2013 Brammer
2013/0211281 A1 8/2013 Ross et al.
2013/0253943 A1 9/2013 Lee et al.
2013/0274069 A1 10/2013 Watterson et al.
2013/0296987 A1 11/2013 Rogers et al.
2013/0318027 A1 11/2013 Almogy et al.
2013/0332616 A1 12/2013 Landwehr
2013/0345025 A1 12/2013 van der Merwe
2014/0006042 A1 1/2014 Keefe et al.
2014/0011640 A1 1/2014 Dugan
2014/0031174 A1 1/2014 Huang
2014/0062900 A1 3/2014 Kaula et al.
2014/0074179 A1 3/2014 Heldman et al.
2014/0089836 A1 3/2014 Damani et al.
2014/0113261 A1 4/2014 Akiba
2014/0113768 A1 4/2014 Lin et al.
2014/0155129 A1 6/2014 Dugan
2014/0163439 A1 6/2014 Uryash et al.
2014/0172442 A1 6/2014 Broderick
2014/0172460 A1 6/2014 Kohli
2014/0188009 A1 7/2014 Lange et al.
2014/0194250 A1 7/2014 Reich et al.
2014/0194251 A1 7/2014 Reich et al.
2014/0207264 A1 7/2014 Quy
2014/0207486 A1 7/2014 Carty et al.
2014/0228649 A1 8/2014 Rayner et al.
2014/0246499 A1 9/2014 Proud et al.
2014/0256511 A1 9/2014 Smith
2014/0257837 A1 9/2014 Walker et al.
2014/0274565 A1 9/2014 Boyette et al.
2014/0274622 A1 9/2014 Leonhard
2014/0303540 A1 10/2014 Baym
2014/0309083 A1 10/2014 Dugan
2014/0315689 A1 10/2014 Vauquelin et al.
2014/0322686 A1 10/2014 Kang
2014/0347265 A1 11/2014 Aimone et al.
2014/0371816 A1 12/2014 Matos
2014/0372133 A1 12/2014 Austrum et al.
2015/0025816 A1 1/2015 Ross
2015/0045700 A1 2/2015 Cavanagh et al.
2015/0051721 A1 2/2015 Cheng
2015/0065213 A1 3/2015 Dugan
2015/0073814 A1 3/2015 Linebaugh
2015/0088544 A1 3/2015 Goldberg
2015/0094192 A1 4/2015 Skwortsow et al.
2015/0099458 A1 4/2015 Weisner et al.
2015/0099952 A1 4/2015 Lain et al.
2015/0112230 A1 4/2015 Iglesias
2015/0112702 A1 4/2015 Joao et al.
2015/0130830 A1 5/2015 Nagasaki
2015/0141200 A1 5/2015 Murray et al.
2015/0149217 A1 5/2015 Kaburagi
2015/0151162 A1 6/2015 Dugan
2015/0158549 A1 6/2015 Gros et al.
2015/0161331 A1 6/2015 Oleynik
2015/0161876 A1 6/2015 Castillo
2015/0174446 A1 6/2015 Chiang
2015/0196805 A1 7/2015 Koduri
2015/0217056 A1 8/2015 Kadavy et al.
2015/0257679 A1 9/2015 Ross
2015/0265209 A1 9/2015 Zhang
2015/0290061 A1 10/2015 Stafford et al.
2015/0339442 A1 11/2015 Oleynik
2015/0341812 A1 11/2015 Dion et al.
2015/0351664 A1 12/2015 Ross
2015/0351665 A1 12/2015 Ross
2015/0360069 A1 12/2015 Marti et al.
2015/0379232 A1 12/2015 Mainwaring et al.
2015/0379430 A1 12/2015 Dirac et al.
2016/0007885 A1 1/2016 Basta et al.
2016/0015995 A1 1/2016 Leung et al.
2016/0045170 A1 2/2016 Migita
2016/0096073 A1 4/2016 Rahman et al.
2016/0117471 A1 4/2016 Belt et al.
2016/0132643 A1 5/2016 Radhakrishna et al.
2016/0140319 A1 5/2016 Stark
2016/0143593 A1 5/2016 Fu et al.
2016/0151670 A1 6/2016 Dugan
2016/0158534 A1 6/2016 Guarraia et al.
2016/0166833 A1 6/2016 Bum
2016/0166881 A1 6/2016 Ridgel et al.
2016/0193306 A1 7/2016 Rabovsky et al.
2016/0213924 A1 7/2016 Coleman
2016/0275259 A1 9/2016 Nolan et al.
2016/0287166 A1 10/2016 Tran
2016/0302721 A1 10/2016 Wiedenhoefer et al.
2016/0317869 A1 11/2016 Dugan
2016/0322078 A1 11/2016 Bose et al.
2016/0325140 A1 11/2016 Wu
2016/0332028 A1 11/2016 Melnik
2016/0345841 A1 12/2016 Jang et al.
2016/0354636 A1 12/2016 Jang
2016/0361597 A1 12/2016 Cole et al.
2016/0373477 A1 12/2016 Moyle

(56) **References Cited**

U.S. PATENT DOCUMENTS

2017/0004260 A1 1/2017 Moturu et al.
2017/0011179 A1 1/2017 Arshad et al.
2017/0032092 A1 2/2017 Mink et al.
2017/0033375 A1 2/2017 Ohmori et al.
2017/0042467 A1 2/2017 Herr et al.
2017/0046488 A1 2/2017 Pereira
2017/0065851 A1 3/2017 Deluca et al.
2017/0080320 A1 3/2017 Smith
2017/0091422 A1 3/2017 Kumar et al.
2017/0095670 A1 4/2017 Ghaffari et al.
2017/0095692 A1 4/2017 Chang et al.
2017/0095693 A1 4/2017 Chang et al.
2017/0100637 A1 4/2017 Princen et al.
2017/0106242 A1 4/2017 Dugan
2017/0128769 A1 5/2017 Long et al.
2017/0132947 A1 5/2017 Maeda et al.
2017/0136296 A1 5/2017 Barrera et al.
2017/0143261 A1 5/2017 Wiedenhoefer et al.
2017/0147752 A1 5/2017 Toru
2017/0147789 A1 5/2017 Wiedenhoefer et al.
2017/0148297 A1 5/2017 Ross
2017/0168555 A1 6/2017 Munoz et al.
2017/0181698 A1 6/2017 Wiedenhoefer et al.
2017/0190052 A1 7/2017 Jaekel et al.
2017/0202724 A1 7/2017 De Rossi
2017/0209766 A1 7/2017 Riley et al.
2017/0220751 A1 8/2017 Davis
2017/0228517 A1 8/2017 Saliman et al.
2017/0235882 A1 8/2017 Orlov et al.
2017/0235906 A1 8/2017 Dorris et al.
2017/0243028 A1 8/2017 LaFever et al.
2017/0262604 A1 9/2017 Francois
2017/0266501 A1 9/2017 Sanders et al.
2017/0270260 A1 9/2017 Shetty
2017/0278209 A1 9/2017 Olsen et al.
2017/0282015 A1 10/2017 Wicks et al.
2017/0283508 A1 10/2017 Demopulos et al.
2017/0286621 A1 10/2017 Cox
2017/0296861 A1 10/2017 Burkinshaw
2017/0300654 A1 10/2017 Stein et al.
2017/0304024 A1 10/2017 Nobrega
2017/0312614 A1 11/2017 Tran et al.
2017/0323481 A1 11/2017 Tran et al.
2017/0329917 A1* 11/2017 McRaith G16H 20/00
2017/0329933 A1 11/2017 Brust
2017/0333755 A1 11/2017 Rider
2017/0337033 A1 11/2017 Duyan et al.
2017/0337334 A1 11/2017 Stanczak
2017/0344726 A1 11/2017 Duffy et al.
2017/0347923 A1 12/2017 Roh
2017/0360586 A1 12/2017 Dempers et al.
2017/0368413 A1 12/2017 Shavit
2018/0017806 A1 1/2018 Wang et al.
2018/0036593 A1 2/2018 Ridgel et al.
2018/0052962 A1 2/2018 Van Der Koijk et al.
2018/0056104 A1 3/2018 Cromie et al.
2018/0060494 A1 3/2018 Dias et al.
2018/0071572 A1 3/2018 Gomberg et al.
2018/0075205 A1 3/2018 Moturu et al.
2018/0078843 A1 3/2018 Tran et al.
2018/0085615 A1 3/2018 Astolfi et al.
2018/0096111 A1 4/2018 Wells et al.
2018/0099178 A1 4/2018 Schaefer et al.
2018/0102190 A1 4/2018 Hogue et al.
2018/0113985 A1 4/2018 Gandy et al.
2018/0116741 A1 5/2018 Garcia Kilroy et al.
2018/0117417 A1 5/2018 Davis
2018/0130555 A1 5/2018 Chronis et al.
2018/0140927 A1 5/2018 Kito
2018/0146870 A1* 5/2018 Shemesh A61B 5/02416
2018/0177612 A1 6/2018 Trabish et al.
2018/0178061 A1 6/2018 O'larte et al.
2018/0199855 A1 7/2018 Odame et al.
2018/0200577 A1 7/2018 Dugan
2018/0220935 A1 8/2018 Tadano et al.
2018/0228682 A1 8/2018 Bayerlein et al.
2018/0236307 A1 8/2018 Hyde et al.
2018/0240552 A1 8/2018 Tuyl et al.
2018/0253991 A1 9/2018 Tang et al.
2018/0255110 A1 9/2018 Dowlatkhah et al.
2018/0256079 A1 9/2018 Yang et al.
2018/0263530 A1 9/2018 Jung
2018/0263535 A1 9/2018 Cramer
2018/0263552 A1 9/2018 Graman et al.
2018/0264312 A1 9/2018 Pompile et al.
2018/0271432 A1 9/2018 Auchinleck et al.
2018/0272184 A1 9/2018 Vassilaros et al.
2018/0280784 A1 10/2018 Romeo et al.
2018/0296143 A1 10/2018 Anderson et al.
2018/0296157 A1 10/2018 Bleich et al.
2018/0326243 A1 11/2018 Badi et al.
2018/0330058 A1 11/2018 Bates
2018/0330810 A1 11/2018 Gamarnik
2018/0330824 A1 11/2018 Athey et al.
2018/0290017 A1 12/2018 Fung
2018/0353812 A1 12/2018 Lannon et al.
2018/0360340 A1 12/2018 Rehse et al.
2018/0366225 A1 12/2018 Mansi et al.
2018/0373844 A1 12/2018 Ferrandez-Escamez et al.
2019/0009135 A1 1/2019 Wu
2019/0019163 A1 1/2019 Batey et al.
2019/0019573 A1 1/2019 Lake et al.
2019/0019578 A1 1/2019 Vaccaro
2019/0030415 A1 1/2019 Volpe, Jr.
2019/0031284 A1 1/2019 Fuchs
2019/0046794 A1 2/2019 Goodall et al.
2019/0060708 A1 2/2019 Fung
2019/0065970 A1 2/2019 Bonutti et al.
2019/0066832 A1 2/2019 Kang et al.
2019/0076701 A1 3/2019 Dugan
2019/0080802 A1 3/2019 Ziobro et al.
2019/0083846 A1 3/2019 Eder
2019/0088356 A1 3/2019 Oliver et al.
2019/0090744 A1 3/2019 Mahfouz
2019/0096534 A1 3/2019 Joao
2019/0105551 A1 4/2019 Ray
2019/0111299 A1 4/2019 Radcliffe et al.
2019/0115097 A1 4/2019 Macoviak et al.
2019/0117128 A1 4/2019 Chen et al.
2019/0117156 A1 4/2019 Howard et al.
2019/0118038 A1 4/2019 Tana et al.
2019/0126099 A1 5/2019 Hoang
2019/0132948 A1 5/2019 Longinotti-Buitoni et al.
2019/0134454 A1 5/2019 Mahoney et al.
2019/0137988 A1 5/2019 Cella et al.
2019/0143191 A1 5/2019 Ran et al.
2019/0145774 A1 5/2019 Ellis
2019/0163876 A1 5/2019 Remme et al.
2019/0167988 A1 6/2019 Shahriari et al.
2019/0172587 A1 6/2019 Park et al.
2019/0175988 A1 6/2019 Volterrani et al.
2019/0183715 A1 6/2019 Kapure et al.
2019/0200920 A1 7/2019 Tien et al.
2019/0209891 A1 7/2019 Fung
2019/0214119 A1 7/2019 Wachira et al.
2019/0223797 A1 7/2019 Tran
2019/0228856 A1 7/2019 Leifer
2019/0240103 A1 8/2019 Hepler et al.
2019/0240541 A1 8/2019 Denton et al.
2019/0244540 A1 8/2019 Errante et al.
2019/0251456 A1 8/2019 Constantin
2019/0261959 A1 8/2019 Frankel
2019/0262084 A1 8/2019 Roh
2019/0269343 A1 9/2019 Ramos Murguialday et al.
2019/0274523 A1 9/2019 Bates et al.
2019/0275368 A1 9/2019 Maroldi
2019/0290964 A1 9/2019 Oren
2019/0304584 A1 10/2019 Savolainen
2019/0307983 A1 10/2019 Goldman
2019/0314681 A1 10/2019 Yang
2019/0344123 A1 11/2019 Rubin et al.
2019/0354632 A1 11/2019 Mital et al.
2019/0362242 A1 11/2019 Pillai et al.
2019/0366146 A1 12/2019 Tong et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2019/0385199 A1 12/2019 Bender et al.
2019/0388728 A1 12/2019 Wang et al.
2019/0392936 A1 12/2019 Arric et al.
2019/0392939 A1 12/2019 Basta et al.
2020/0005928 A1 1/2020 Daniel
2020/0034707 A1 1/2020 Kivatinos et al.
2020/0038703 A1 2/2020 Cleary et al.
2020/0051446 A1 2/2020 Rubinstein et al.
2020/0066390 A1 2/2020 Svendrys et al.
2020/0085300 A1 3/2020 Kwatra et al.
2020/0090802 A1 3/2020 Maron
2020/0093418 A1 3/2020 Kluger et al.
2020/0143922 A1 5/2020 Chekroud et al.
2020/0151595 A1 5/2020 Jayalath et al.
2020/0151646 A1 5/2020 De La Fuente Sanchez
2020/0152339 A1 5/2020 Pulitzer et al.
2020/0160198 A1 5/2020 Reeves et al.
2020/0170876 A1 6/2020 Kapure et al.
2020/0176098 A1 6/2020 Lucas et al.
2020/0197744 A1 6/2020 Schweighofer
2020/0221975 A1 7/2020 Basta et al.
2020/0237291 A1 7/2020 Raja
2020/0237452 A1 7/2020 Wolf et al.
2020/0267487 A1 8/2020 Siva
2020/0275886 A1 9/2020 Mason
2020/0289045 A1 9/2020 Hacking et al.
2020/0289046 A1 9/2020 Hacking et al.
2020/0289879 A1 9/2020 Hacking et al.
2020/0289880 A1 9/2020 Hacking et al.
2020/0289881 A1 9/2020 Hacking et al.
2020/0289889 A1 9/2020 Hacking et al.
2020/0293712 A1 9/2020 Potts et al.
2020/0303063 A1 9/2020 Sharma et al.
2020/0312447 A1 10/2020 Bohn et al.
2020/0334972 A1 10/2020 Gopalakrishnan
2020/0353314 A1 11/2020 Messinger
2020/0357299 A1 11/2020 Patel et al.
2020/0365256 A1 11/2020 Hayashitani et al.
2020/0395112 A1 12/2020 Ronner
2020/0401224 A1 12/2020 Cotton
2020/0402662 A1 12/2020 Esmailian et al.
2020/0410374 A1 12/2020 White
2020/0410385 A1 12/2020 Otsuki
2020/0411162 A1 12/2020 Lien et al.
2021/0005224 A1 1/2021 Rothschild et al.
2021/0005319 A1 1/2021 Otsuki et al.
2021/0008413 A1 1/2021 Asikainen et al.
2021/0027889 A1 1/2021 Neil et al.
2021/0035674 A1 2/2021 Volosin et al.
2021/0050086 A1 2/2021 Rose et al.
2021/0065855 A1 3/2021 Pepin et al.
2021/0074178 A1 3/2021 Ilan et al.
2021/0076981 A1 3/2021 Hacking et al.
2021/0077860 A1 3/2021 Posnack et al.
2021/0098129 A1 4/2021 Neumann
2021/0101051 A1 4/2021 Posnack et al.
2021/0113890 A1 4/2021 Posnack et al.
2021/0127974 A1 5/2021 Mason et al.
2021/0128255 A1 5/2021 Mason et al.
2021/0128978 A1 5/2021 Gilstrom et al.
2021/0134412 A1 5/2021 Guaneri et al.
2021/0134425 A1 5/2021 Mason et al.
2021/0134428 A1 5/2021 Mason et al.
2021/0134430 A1 5/2021 Mason et al.
2021/0134432 A1 5/2021 Mason et al.
2021/0134456 A1 5/2021 Posnack et al.
2021/0134457 A1 5/2021 Mason et al.
2021/0134458 A1 5/2021 Mason et al.
2021/0134463 A1 5/2021 Mason et al.
2021/0138304 A1 5/2021 Mason et al.
2021/0142875 A1 5/2021 Mason et al.
2021/0142893 A1 5/2021 Guaneri et al.
2021/0142898 A1 5/2021 Mason et al.
2021/0142903 A1 5/2021 Mason et al.
2021/0144074 A1 5/2021 Guaneri et al.
2021/0186419 A1 6/2021 Van Ee et al.
2021/0187348 A1 6/2021 Phillips et al.
2021/0202090 A1 7/2021 ODonovan et al.
2021/0202103 A1 7/2021 Bostic et al.
2021/0236020 A1 8/2021 Matijevich et al.
2021/0244998 A1 8/2021 Hacking et al.
2021/0245003 A1 8/2021 Turner
2021/0251562 A1 8/2021 Jain
2021/0272677 A1 9/2021 Barbee
2021/0338469 A1 11/2021 Dempers
2021/0343384 A1 11/2021 Purushothaman et al.
2021/0345879 A1 11/2021 Mason et al.
2021/0345975 A1 11/2021 Mason et al.
2021/0350888 A1 11/2021 Guaneri et al.
2021/0350898 A1 11/2021 Mason et al.
2021/0350899 A1 11/2021 Mason et al.
2021/0350901 A1 11/2021 Mason et al.
2021/0350902 A1 11/2021 Mason et al.
2021/0350914 A1 11/2021 Guaneri et al.
2021/0350926 A1 11/2021 Mason et al.
2021/0361514 A1 11/2021 Choi et al.
2021/0366587 A1 11/2021 Mason et al.
2021/0383909 A1 12/2021 Mason et al.
2021/0391091 A1 12/2021 Mason
2021/0398668 A1 12/2021 Chock et al.
2021/0407670 A1 12/2021 Mason et al.
2021/0407681 A1 12/2021 Mason et al.
2022/0000556 A1 1/2022 Casey et al.
2022/0015838 A1 1/2022 Posnack et al.
2022/0016480 A1 1/2022 Bissonnette et al.
2022/0016482 A1 1/2022 Bissonnette
2022/0016485 A1 1/2022 Bissonnette et al.
2022/0016486 A1 1/2022 Bissonnette
2022/0020469 A1 1/2022 Tanner
2022/0044806 A1 2/2022 Sanders et al.
2022/0047921 A1 2/2022 Bissonnette et al.
2022/0079690 A1 3/2022 Mason et al.
2022/0080256 A1 3/2022 Am et al.
2022/0080265 A1 3/2022 Watterson
2022/0105384 A1 4/2022 Hacking et al.
2022/0105385 A1 4/2022 Hacking et al.
2022/0105390 A1 4/2022 Yuasa
2022/0115133 A1 4/2022 Mason et al.
2022/0118218 A1 4/2022 Bense et al.
2022/0122724 A1 4/2022 Durlach et al.
2022/0126169 A1 4/2022 Mason
2022/0133576 A1 5/2022 Choi et al.
2022/0148725 A1 5/2022 Mason et al.
2022/0158916 A1 5/2022 Mason et al.
2022/0176039 A1 6/2022 Lintereur et al.
2022/0181004 A1 6/2022 Zilca et al.
2022/0193491 A1 6/2022 Mason et al.
2022/0230729 A1 7/2022 Mason
2022/0238222 A1 7/2022 Neuberg
2022/0238223 A1 7/2022 Mason et al.
2022/0258935 A1 8/2022 Kraft
2022/0262483 A1 8/2022 Rosenberg et al.
2022/0262504 A1 8/2022 Bratty et al.
2022/0266094 A1 8/2022 Mason et al.
2022/0270738 A1 8/2022 Mason et al.
2022/0273985 A1 9/2022 Jeong et al.
2022/0273986 A1 9/2022 Mason
2022/0288460 A1 9/2022 Mason
2022/0288461 A1 9/2022 Ashley et al.
2022/0288462 A1 9/2022 Ashley et al.
2022/0293257 A1 9/2022 Guaneri et al.
2022/0300787 A1 9/2022 Wall et al.
2022/0304881 A1 9/2022 Choi et al.
2022/0304882 A1 9/2022 Choi
2022/0305328 A1 9/2022 Choi et al.
2022/0314072 A1 10/2022 Bissonnette et al.
2022/0314075 A1 10/2022 Mason et al.
2022/0323826 A1 10/2022 Khurana
2022/0327714 A1 10/2022 Cook et al.
2022/0327807 A1 10/2022 Cook et al.
2022/0328181 A1 10/2022 Mason et al.
2022/0330823 A1 10/2022 Janssen
2022/0331663 A1 10/2022 Mason
2022/0338761 A1 10/2022 Maddahi et al.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2022/0339052	A1	10/2022	Kim
2022/0339501	A1	10/2022	Mason et al.
2022/0370851	A1	11/2022	Guidarelli et al.
2022/0384012	A1	12/2022	Mason
2022/0392591	A1	12/2022	Guaneri et al.
2022/0395232	A1	12/2022	Locke
2022/0401783	A1	12/2022	Choi
2022/0415469	A1	12/2022	Mason
2022/0415471	A1	12/2022	Mason
2023/0001268	A1	1/2023	Bissonnette et al.
2023/0013530	A1	1/2023	Mason
2023/0014598	A1	1/2023	Mason et al.
2023/0029639	A1	2/2023	Roy
2023/0047253	A1	2/2023	Gnanasambandam et al.
2023/0048040	A1	2/2023	Hacking et al.
2023/0051751	A1	2/2023	Hacking et al.
2023/0058605	A1	2/2023	Mason
2023/0060039	A1	2/2023	Mason
2023/0072368	A1	3/2023	Mason
2023/0078793	A1	3/2023	Mason
2023/0119461	A1	4/2023	Mason
2023/0190100	A1	6/2023	Stump
2023/0201656	A1	6/2023	Hacking et al.
2023/0207097	A1	6/2023	Mason
2023/0207124	A1	6/2023	Walsh et al.
2023/0215539	A1	7/2023	Rosenberg et al.
2023/0215552	A1	7/2023	Khotilovich et al.
2023/0245747	A1	8/2023	Rosenberg et al.
2023/0245748	A1	8/2023	Rosenberg et al.
2023/0245750	A1	8/2023	Rosenberg et al.
2023/0245751	A1	8/2023	Rosenberg et al.
2023/0253089	A1	8/2023	Rosenberg et al.
2023/0255555	A1	8/2023	Sundaram et al.
2023/0263428	A1	8/2023	Hull et al.
2023/0274813	A1	8/2023	Rosenberg et al.
2023/0282329	A1	9/2023	Mason et al.
2023/0364472	A1	11/2023	Posnack
2023/0368886	A1	11/2023	Rosenberg
2023/0377711	A1	11/2023	Rosenberg
2023/0377712	A1	11/2023	Rosenberg
2023/0386639	A1	11/2023	Rosenberg
2023/0395231	A1	12/2023	Rosenberg
2023/0395232	A1	12/2023	Rosenberg
2024/0029856	A1	1/2024	Rosenberg

FOREIGN PATENT DOCUMENTS

CN	2885238	Y	4/2007
CN	101964151	A	2/2011
CN	201889024	U	7/2011
CN	102670381	A	9/2012
CN	103263336	A	8/2013
CN	103390357	A	11/2013
CN	103473631	A	12/2013
CN	103488880	A	1/2014
CN	103501328	A	1/2014
CN	103721343	A	4/2014
CN	203677851	U	7/2014
CN	104335211	A	2/2015
CN	105683977	A	6/2016
CN	103136447	B	8/2016
CN	105894088	A	8/2016
CN	105930668	A	9/2016
CN	205626871	U	10/2016
CN	106127646	A	11/2016
CN	106236502	A	12/2016
CN	106510985	A	3/2017
CN	106621195	A	5/2017
CN	107066819	A	8/2017
CN	107430641	A	12/2017
CN	107551475	A	1/2018
CN	107736982	A	2/2018
CN	107930021	A	4/2018
CN	207220817	U	4/2018
CN	108078737	A	5/2018
CN	208224811	A	12/2018
CN	109191954	A	1/2019
CN	109363887	A	2/2019
CN	208573971	U	3/2019
CN	110148472	A	8/2019
CN	110201358	A	9/2019
CN	110215188	A	9/2019
CN	110322957	A	10/2019
CN	110808092	A	2/2020
CN	110931103	A	3/2020
CN	110993057	A	4/2020
CN	111105859	A	5/2020
CN	111111110	A	5/2020
CN	111370088	A	7/2020
CN	111460305	A	7/2020
CN	111790111	A	10/2020
CN	112071393	A	12/2020
CN	212141371	U	12/2020
CN	112289425	A	1/2021
CN	212624809	U	2/2021
CN	112603295	A	4/2021
CN	213190965	U	5/2021
CN	113384850	A	9/2021
CN	113499572	A	10/2021
CN	215136488	U	12/2021
CN	113885361	A	1/2022
CN	114049961	A	2/2022
CN	114203274	A	3/2022
CN	216258145	U	4/2022
CN	114632302	A	6/2022
CN	114694824	A	7/2022
CN	114898832	A	8/2022
CN	114983760	A	9/2022
CN	217472652	U	9/2022
CN	110270062	B	10/2022
CN	218420859	U	2/2023
CN	115954081	A	4/2023
DE	102018202497	A1	8/2018
DE	102018211212	A1	1/2019
DE	102019108425	B3	8/2020
EP	0383137	A2	8/1990
EP	0919259	A1	6/1999
EP	1159989	A1	12/2001
EP	1391179	A1	2/2004
EP	1968028		9/2008
EP	2575064	A1	4/2013
EP	1909730	B1	4/2014
EP	2815242	A4	12/2014
EP	2869805	A	5/2015
EP	2997951	A1	3/2016
EP	2688472	B1	4/2016
EP	3323473	A1	5/2018
EP	3627514	A1	3/2020
EP	3671700	A1	6/2020
EP	3688537	A1	8/2020
EP	3731733	A1	11/2020
EP	3984508	A1	4/2022
EP	3984509	A1	4/2022
EP	3984510	A1	4/2022
EP	3984511	A1	4/2022
EP	3984512	A1	4/2022
EP	3984513	A1	4/2022
EP	4054699	A1	9/2022
EP	4112033	A1	1/2023
FR	3127393	A1	3/2023
GB	2512431	A	10/2014
GB	2591542	B	3/2022
IN	201811043670	A	7/2018
JP	2000005339	A	1/2000
JP	2003225875	A	8/2003
JP	2005227928	A	8/2005
JP	2005227928	A1	8/2005
JP	2009112336	A	5/2009
JP	2013515995	A	5/2013
JP	2014104139	A	6/2014
JP	3193662	U	10/2014
JP	3198173	U	6/2015
JP	5804063	B2	11/2015
JP	6659831	B2	10/2017

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

JP	2018102842	A	7/2018
JP	2019028647	A	2/2019
JP	2019134909	A	8/2019
JP	6573739	B1	9/2019
JP	2020057082	A	4/2020
JP	6710357	B1	6/2020
JP	6775757	B1	10/2020
JP	2021026768	A	2/2021
JP	2021027917	A	2/2021
JP	6871379	B2	5/2021
JP	2022521378	A	4/2022
JP	3238491	U	7/2022
JP	7198364	B2	12/2022
JP	7202474	B2	1/2023
JP	7231750	B2	3/2023
JP	7231751	B2	3/2023
JP	7231752	B2	3/2023
KR	20020009724	A	2/2002
KR	200276919	Y1	5/2002
KR	20020065253	A	8/2002
KR	100582596	B1	5/2006
KR	101042258	B1	6/2011
KR	20110099953	A	9/2011
KR	101258250	B1	4/2013
KR	101325581	B1	11/2013
KR	20140128630	A	11/2014
KR	20150017693	A	2/2015
KR	20150078191	A	7/2015
KR	101580071	B1	12/2015
KR	101647620	B1	8/2016
KR	20160093990	A	8/2016
KR	20170038837	A	4/2017
KR	20180004928	A	1/2018
KR	20190011885	A	2/2019
KR	20190029175	A	3/2019
KR	101988167	B1	6/2019
KR	102116664	B1	7/2019
KR	101969392	B1	8/2019
KR	102055279	B1	12/2019
KR	102088333	B1	3/2020
KR	102116968	B1	3/2020
KR	20200025290	A	3/2020
KR	20200029180	A	3/2020
KR	102097190	B1	4/2020
KR	102162522	B1	4/2020
KR	102142713	B1	5/2020
KR	20200056233	A	5/2020
KR	102120828	B1	6/2020
KR	102121586	B1	6/2020
KR	20200119665	A	10/2020
KR	102173553	B1	11/2020
KR	102180079	B1	11/2020
KR	102224618	B1	11/2020
KR	102188766	B1	12/2020
KR	102196793	B1	12/2020
KR	20210006212	A	1/2021
KR	102224188	B1	3/2021
KR	102246049	B1	4/2021
KR	102246050	B1	4/2021
KR	102246051	B1	4/2021
KR	102246052	B1	4/2021
KR	20210052028	A	5/2021
KR	102264498	B1	6/2021
KR	102352602	B1	1/2022
KR	102352603	B1	1/2022
KR	102352604	B1	1/2022
KR	20220004639	A	1/2022
KR	102387577	B1	4/2022
KR	102421437	B1	7/2022
KR	20220102207	A	7/2022
KR	102427545	B1	8/2022
KR	102467495	B1	11/2022
KR	102467496	B1	11/2022
KR	102469723	B1	11/2022
KR	102471990	B1	11/2022
KR	20220145989	A	11/2022
KR	20220156134	A	11/2022
KR	102502744	B1	2/2023
KR	20230019349	A	2/2023
KR	20230019350	A	2/2023
KR	20230026556	A	2/2023
KR	20230026668	A	2/2023
KR	20230040526		3/2023
KR	20230050506	A	4/2023
KR	20230056118	A	4/2023
KR	102528503	B1	5/2023
KR	102531930	B1	5/2023
KR	102532766	B1	5/2023
KR	102539190	B1	6/2023
RU	2014131288	A	2/2016
RU	2607953	C2	1/2017
TW	M474545	U	3/2014
TW	M638437	U	3/2023
WO	0149235	A2	7/2001
WO	0151083	A2	7/2001
WO	2001050387	A1	7/2001
WO	2001056465	A1	8/2001
WO	02062211	A2	8/2002
WO	02093312	A2	11/2002
WO	2003043494		5/2003
WO	2005018453	A1	3/2005
WO	2006004430	A2	1/2006
WO	2007102709	A1	9/2007
WO	2008114291	A1	9/2008
WO	2009003170	A1	12/2008
WO	2009008968	A1	1/2009
WO	2011025322	A2	3/2011
WO	2012128801	A1	9/2012
WO	2013002568	A2	1/2013
WO	2023164292	A1	3/2013
WO	2013122839	A1	8/2013
WO	2014011447	A1	1/2014
WO	2014163976	A1	10/2014
WO	2015026744	A1	2/2015
WO	2015065298	A1	5/2015
WO	2015082555	A1	6/2015
WO	2016151364	A1	9/2016
WO	2016154318	A1	9/2016
WO	2017030781	A1	2/2017
WO	2017166074	A1	5/2017
WO	2017091691	A1	6/2017
WO	2017165238	A1	9/2017
WO	2018081795	A1	5/2018
WO	2018171853	A1	9/2018
WO	2019022706	A1	1/2019
WO	2019204876	A1	4/2019
WO	2019143940	A1	7/2019
WO	2020185769	A1	3/2020
WO	2020075190	A1	4/2020
WO	2020130979	A1	6/2020
WO	2020149815	A2	7/2020
WO	2020229705	A1	11/2020
WO	2020245727	A1	12/2020
WO	2020249855	A1	12/2020
WO	2020252599	A1	12/2020
WO	2020256577	A1	12/2020
WO	2021021447	A1	2/2021
WO	2021022003	A1	2/2021
WO	2021038980	A1	3/2021
WO	2021055427	A1	3/2021
WO	2021055491	A1	3/2021
WO	2021061061	A1	4/2021
WO	2021081094	A1	4/2021
WO	2021090267	A1	5/2021
WO	2021138620	A1	7/2021
WO	2021216881	A1	10/2021
WO	2021236542	A1	11/2021
WO	2021236961	A1	11/2021
WO	2021262809	A1	12/2021
WO	2022047006	A1	3/2022
WO	2022092493	A1	5/2022
WO	2022092494	A1	5/2022
WO	2022212883	A1	10/2022
WO	2022212921	A1	10/2022

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

WO	2022216498	A1	10/2022
WO	2022251420	A1	12/2022
WO	2023008680	A1	2/2023
WO	2023008681	A1	2/2023
WO	2023022319	A1	2/2023
WO	2023022320	A1	2/2023
WO	2023052695	A1	4/2023
WO	2023091496	A1	5/2023
WO	2023215155	A1	11/2023
WO	2023230075	A1	11/2023
WO	2024013267	A1	1/2024
WO	2024107807	A1	5/2024

OTHER PUBLICATIONS

Website for "Esino 2022 Physical Therapy Equipments Arm Fitness Indoor Trainer Leg Spin Cycle Machine Exercise Bike for Elderly," https://www.made-in-china.com/showroom/esinogroup/product-detailYdZtwGhCMKVR/China-Esino-2022-Physical-Therapy-Equipments-Arm-Fitness-Indoor-Trainer-Leg-Spin-Cycle-Machine-Exercise-Bike-for-Elderly.html, retrieved on Aug. 29, 2023, 5 pages.

Abedtash, "An Interoperable Electronic Medical Record-Based Platform For Personalized Predictive Analytics", ProQuest LLC, Jul. 2017, 185 pages.

Website for "Pedal Exerciser", p. 1, retrieved on Sep. 9, 2022 from https://www.vivehealth.com/collections/physical-therapy-equipment/products/pedalexerciser.

Website for "Functional Knee Brace with ROM", p. 1, retrieved on Sep. 9, 2022 from http://medicalbrace.gr/en/product/functional-knee-brace-with-goniometer-mbtelescopicknee/.

Website for "ComfySplints Goniometer Knee", pp. 1-5, retrieved on Sep. 9, 2022 from https://www.comfysplints.com/product/knee-splints/.

Website for "BMI FlexEze Knee Corrective Orthosis (KCO)", pp. 1-4, retrieved on Sep. 9, 2022 from https://orthobmi.com/products/bmi-flexeze%C2%AE-knee-corrective-orthosis-kco.

Website for "Neoprene Knee Brace with goniometer—Patella ROM MB.4070", pp. 1-4, retrieved on Sep. 9, 2022 from https://www.fortuna.com.gr/en/product/neoprene-knee-brace-with-goniometer-patella-rom-mb-4070/.

Kuiken et al., "Computerized Biofeedback Knee Goniometer: Acceptance and Effect on Exercise Behavior in Post-total Knee Arthroplasty Rehabilitation," Biomedical Engineering Faculty Research and Publications, 2004, pp. 1-10.

Ahmed et al., "Artificial intelligence with multi-functional machine learning platform development for better healthcare and precision medicine," Database, 2020, pp. 1-35.

Davenport et al., "The potential for artificial intelligence in healthcare," Digital Technology, Future Healthcare Journal, 2019, pp. 1-5, vol. 6, No. 2.

Website for "OxeFit XS1", pp. 1-3, retrieved on Sep. 9, 2022 from https://www.oxefit.com/xs1.

Website for "Preva Mobile", pp. 1-6, retrieved on Sep. 9, 2022 from https://www.precor.com/en-us/resources/introducing-preva-mobile.

Website for "J-Bike", pp. 1-3, retrieved on Sep. 9, 2022 from https://www.magneticdays.com/en/cycling-for-physical-rehabilitation.

Website for "Excy", pp. 1-12, retrieved on Sep. 9, 2022 from https://excy.com/portable-exercise-rehabilitation-excy-xcs-pro/.

Website for "OxeFit XP1", p. 1, retrieved on Sep. 9, 2022 from https://www.oxefit.com/xp1.

Alcaraz et al., "Machine Learning as Digital Therapy Assessment for Mobile Gait Rehabilitation," 2018 IEEE 28th International Workshop on Machine Learning for Signal Processing (MLSP), Aalborg, Denmark, 2018, 6 pages.

Androutsou et al., "A Smartphone Application Designed to Engage the Elderly in Home-Based Rehabilitation," Frontiers in Digital Health, Sep. 2020, vol. 2, Article 15, 13 pages.

Silva et al., "SapoFitness: A mobile health application for dietary evaluation," 2011 IEEE 13th International Conference on U e-Health Networking, Applications and Services, Columbia, MO, USA, 2011, 6 pages.

Wang et al., "Interactive wearable systems for upper body rehabilitation: a systematic review," Journal of NeuroEngineering and Rehabilitation, 2017, 21 pages.

Marzolini et al., "Eligibility, Enrollment, and Completion of Exercise-Based Cardiac Rehabilitation Following Stroke Rehabilitation: What Are the Barriers?," Physical Therapy, vol. 100, No. 1, 2019, 13 pages.

Nijjar et al., "Randomized Trial of Mindfulness-Based Stress Reduction in Cardiac Patients Eligible for Cardiac Rehabilitation," Scientific Reports, 2019, 12 pages.

Lara et al., "Human-Robot Sensor Interface for Cardiac Rehabilitation," IEEE International Conference on Rehabilitation Robotics, Jul. 2017, 8 pages.

Ishraque et al., "Artificial Intelligence-Based Rehabilitation Therapy Exercise Recommendation System," 2018 IEEE MIT Undergraduate Research Technology Conference (URTC), Cambridge, MA, USA, 2018, 5 pages.

Zakari et al., "Are There Limitations to Exercise Benefits in Peripheral Arterial Disease?," Frontiers in Cardiovascular Medicine, Nov. 2018, vol. 5, Article 173, 12 pages.

You et al., "Including Blood Vasculature into a Game-Theoretic Model of Cancer Dynamics," Games 2019, 10, 13, 22 pages.

Jeong et al., "Computer-assisted upper extremity training using interactive biking exercise (iBikE) platform," Sep. 2012, 34th Annual International Conference of the IEEE EMBS, 5 pages.

Gerbild et al., "Physical Activity to Improve Erectile Dysfunction: A Systematic Review of Intervention Studies," Sexual Medicine, 2018, 15 pages.

Malloy, Online Article "AI-enabled EKGs find difference between numerical age and biological age significantly affects health, longevity", Website: https://newsnetwork.mayoclinic.org/discussion/ai-enabled-ekgs-find-difference-between-numerical-age-and-biological-age-significantly-affects-health-longevity/, Mayo Clinic News Network, May 20, 2021, retrieved: Jan. 23, 2023, p. 1-4.

International Searching Authority, Search Report and Written Opinion for International Application No. PCT/US2021/038617, Mailed Oct. 15, 2021, 12 pages.

Davenport et al., "The Potential For Artificial Intelligence In Healthcare", 2019, Future Healthcare Journal 2019, vol. 6, No. 2: Year: 2019, pp. 1-5.

Ahmed et al., "Artificial Intelligence With Multi-Functional Machine Learning Platform Development For Better Healthcare And Precision Medicine", 2020, Database (Oxford), 2020:baaa010. doi: 10.1093/database/baaa010 (Year: 2020), pp. 1-35.

Ruiz Ivan et al., "Towards a physical rehabilitation system using a telemedicine approach", Computer Methods in Biomechanics and Biomedical Engineering: Imaging & Visualization, vol. 8, No. 6, Jul. 28, 2020, pp. 671-680, XP055914810.

De Canniere Helene et al., "Wearable Monitoring and Interpretable Machine Learning Can Objectively Track Progression in Patients during Cardiac Rehabilitation", Sensors, vol. 20, No. 12, Jun. 26, 2020, XP055914617, pp. 1-15.

Boulanger Pierre et al., "A Low-cost Virtual Reality Bike for Remote Cardiac Rehabilitation", Dec. 7, 2017, Advances in Biometrics: International Conference, ICB 2007, Seoul, Korea, pp. 155-166.

Yin Chieh et al., "A Virtual Reality-Cycling Training System for Lower Limb Balance Improvement", BioMed Research International, vol. 2016, pp. 1-10.

International Search Report and Written Opinion for International Application No. PCT/US2021/032807, Date of Mailing Sep. 6, 2021, 11 pages.

Barrett et al., "Artificial intelligence supported patient self-care in chronic heart failure: a paradigm shift from reactive to predictive, preventive and personalised care," EPMA Journal (2019), pp. 445-464.

Oerkild et al., "Home-based cardiac rehabilitation is an attractive alternative to no cardiac rehabilitation for elderly patients with

(56) **References Cited**

OTHER PUBLICATIONS

coronary heart disease: results from a randomised clinical trial," BMJ Open Accessible Medical Research, Nov. 22, 2012, pp. 1-9.
Bravo-Escobar et al., "Effectiveness and safety of a home-based cardiac rehabilitation programme of mixed surveillance in patients with ischemic heart disease at moderate cardiovascular risk: A randomised, controlled clinical trial," BMC Cardiovascular Disorders, 2017, pp. 1-11, vol. 17:66.
Thomas et al., "Home-Based Cardiac Rehabilitation," Circulation, 2019, pp. e69-e89, vol. 140.
Thomas et al., "Home-Based Cardiac Rehabilitation," Journal of the American College of Cardiology, Nov. 1, 2019, pp. 133-153, vol. 74.
Thomas et al., "Home-Based Cardiac Rehabilitation," HHS Public Access, Oct. 2, 2020, pp. 1-39.
Dittus et al., "Exercise-Based Oncology Rehabilitation: Leveraging the Cardiac Rehabilitation Model," Journal of Cardiopulmonary Rehabilitation and Prevention, 2015, pp. 130-139, vol. 35.
Chen et al., "Home-based cardiac rehabilitation improves quality of life, aerobic capacity, and readmission rates in patients with chronic heart failure," Medicine, 2018, pp. 1-5 vol. 97:4.
Lima de Melo Ghisi et al., "A systematic review of patient education in cardiac patients: Do they increase knowledge and promote health behavior change?," Patient Education and Counseling, 2014, pp. 1-15.
Fang et al., "Use of Outpatient Cardiac Rehabilitation Among Heart Attack Survivors—20 States and the District of Columbia, 2013 and Four States, 2015," Morbidity and Mortality Weekly Report, vol. 66, No. 33, Aug. 25, 2017, pp. 869-873.
Beene et al., "AI and Care Delivery: Emerging Opportunities For Artificial Intelligence To Transform How Care Is Delivered," Nov. 2019, American Hospital Association, pp. 1-12.
Jeong et al., "Computer-assisted upper extremity training using interactive biking exercise (iBikE) platform," Sep. 2012, pp. 1-5, 34th Annual International Conference of the IEEE EMBS.
Jennifer Bresnick, "What is the Role of Natural Language Processing in Healthcare?", pp. 1-7, published Aug. 18, 2016, retrieved on Feb. 1, 2022 from https://healthitanalytics.com/ featu res/what-is-the-role-of-natural-language-processing-in-healthcare.
Alex Bellec, "Part-of-Speech tagging tutorial with the Keras Deep Learning library," pp. 1-16, published Mar. 27, 2018, retrieved on Feb. 1, 2022 from https://becominghuman.ai/part-of-speech-tagging-tutorial-with-the-keras-deep-learning-library-d7f93fa05537.
Kavita Ganesan, All you need to know about text preprocessing for NLP and Machine Learning, pp. 1-14, published Feb. 23, 2019, retrieved on Feb. 1, 2022 from https:// towardsdatascience.com/all-you-need-to-know-about-text-preprocessing-for-nlp-and-machine-learning-bcl c5765ff67.
Badreesh Shetty, "Natural Language Processing (NPL) for Machine Learning," pp. 1-13, published Nov. 24, 2018, retrieved on Feb. 1, 2022 from https://towardsdatascience. com/natural-language-processing-nlp-for-machine-learning-d44498845d5b.
Chrif et al., "Control design for a lower-limb paediatric therapy device using linear motor technology," Article, 2017, pp. 119-127, Science Direct, Switzerland.
Robben et al., "Delta Features From Ambient Sensor Data are Good Predictors of Change in Functional Health," Article, 2016, pp. 2168-2194, vol. 21, No. 4, IEEE Journal of Biomedical and Health Informatics.
Kantoch et al., "Recognition of Sedentary Behavior by Machine Learning Analysis of Wearable Sensors during Activities of Daily Living for Telemedical Assessment of Cardiovascular Risk," Article, 2018, 17 pages, Sensors, Poland.
Warburton et al., "International Launch of the PAR-•Q+ and ePAR-med-•X+ Validation of the PAR-•Q+ and ePARmed••X+," Health & Fitness Journal of Canada, 2011, 9 pages, vol. 4, No. 2.
Jeong et al., "Remotely controlled biking is associated with improved adherence to prescribed cycling speed," Technology and Health Care 23, 2015, 7 pages.
Laustsen et al., "Telemonitored exercise-based cardiac rehabilitation improves physical capacity and health-related quality of life," Journal of Telemedicine and Telecare, 2020, DOI: 10.1177/1357633X18792808, 9 pages.
Blasiak et al., "Curate.AI: Optimizing Personalized Medicine with Artificial Intelligence,"SLAS Technology: Translating Life Sciences Innovation, 2020, 11 pages.
Ahmed et al., "Artificial Intelligence With Multi-Functional Machine Learning Platform Development For Better Healthcare And Precision Medicine," Database (Oxford), 2020, pp. 1-35, vol. 2020.
Davenport et al., "The Potential For Artificial Intelligence in Healthcare," Future Healthcare Journal, 2019, pp. 94-98, vol. 6, No. 2.

* cited by examiner

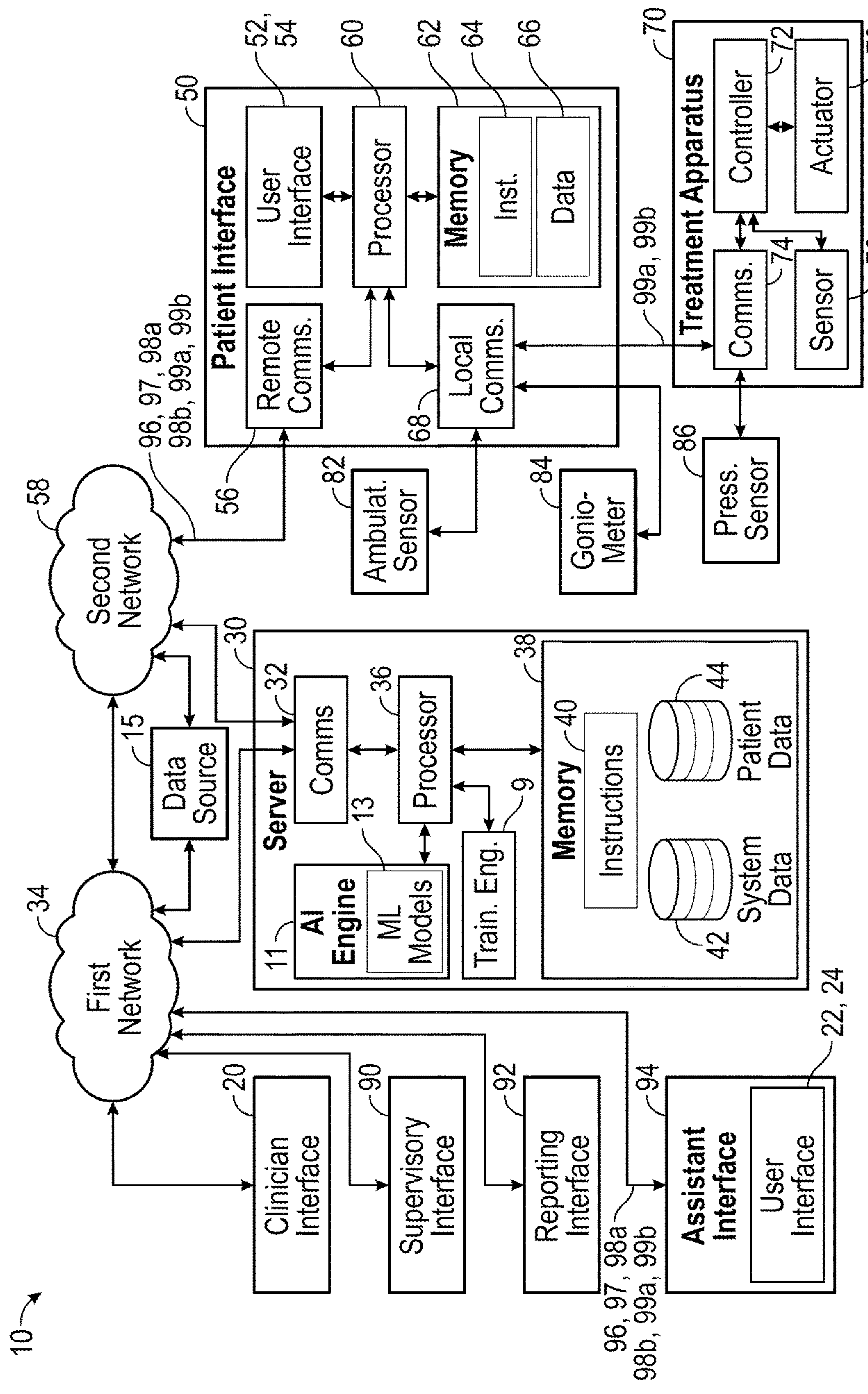

10
First Network
34
Second Network
58
Data Source
15
Server
30
Comms
32
Processor
36
AI Engine
11
ML Models
13
Train. Eng.
9
Memory
38
Instructions
40
System Data
42
Patient Data
44
Clinician Interface
20
Supervisory Interface
90
Reporting Interface
92
Assistant Interface
94
User Interface
22, 24
96, 97, 98a
98b, 99a, 99b
Patient Interface
50
User Interface
52, 54
Processor
60
Memory
62
Inst.
64
Data
66
Remote Comms.
56
Local Comms.
68
Ambulat. Sensor
82
Gonio-Meter
84
Press. Sensor
86
Treatment Apparatus
70
Controller
72
Actuator
78
Comms.
74
Sensor
76
99a, 99b

FIG. 1

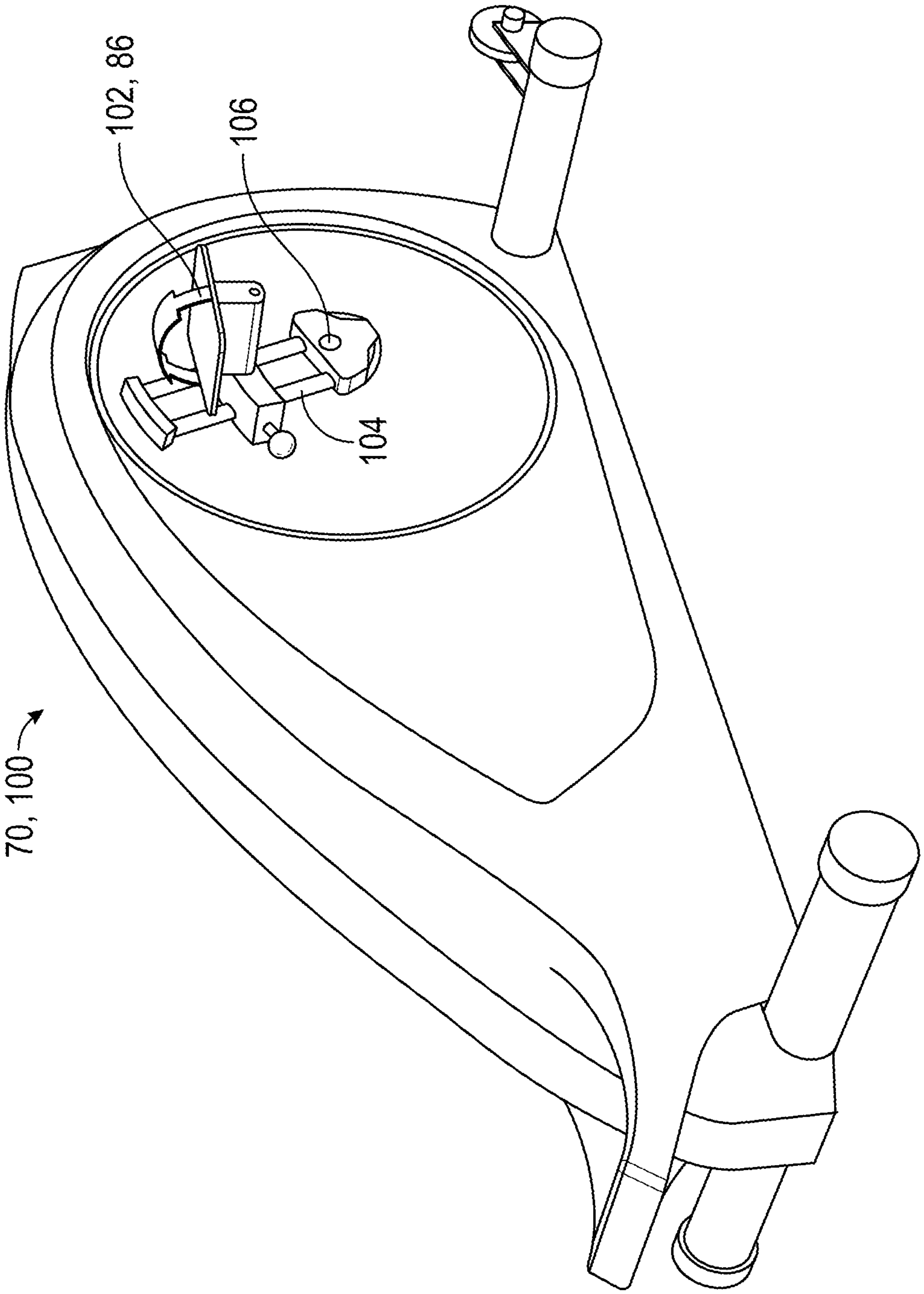


FIG. 2

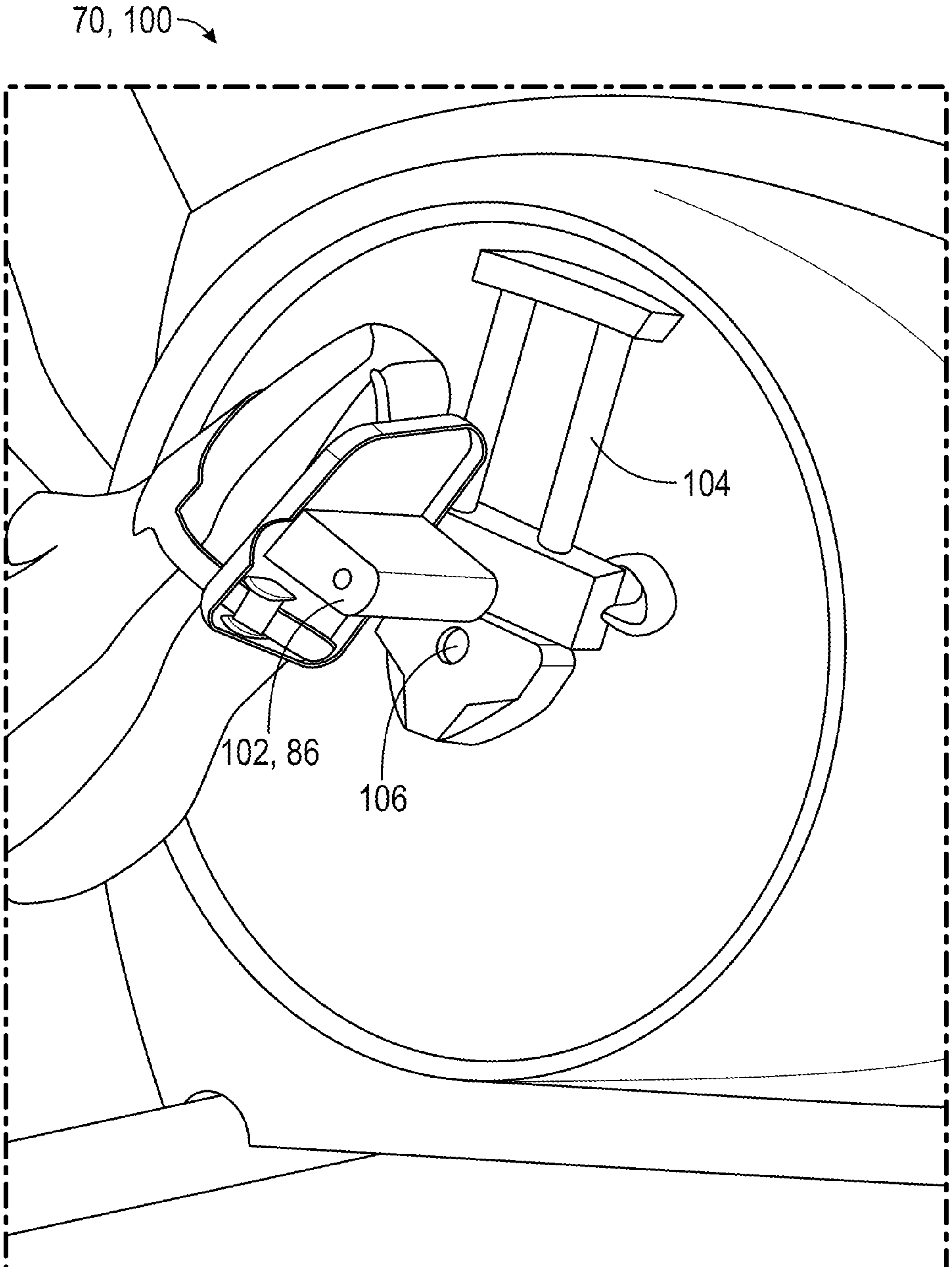


FIG. 3

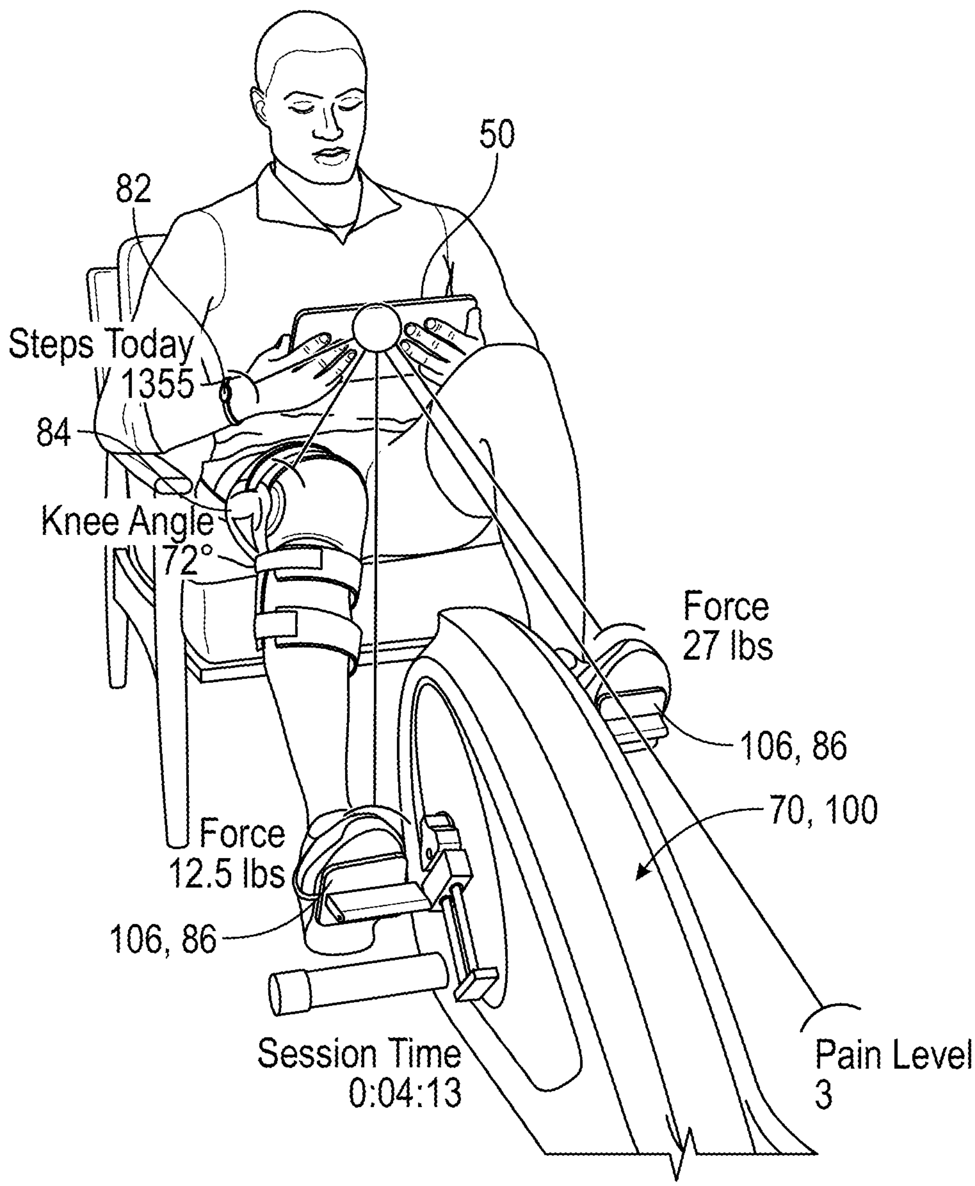

50
82
Steps Today
1355
84
Knee Angle
72°
Force
27 lbs
106, 86
70, 100
Force
12.5 lbs
106, 86
Session Time
0:04:13
Pain Level
3

FIG. 4

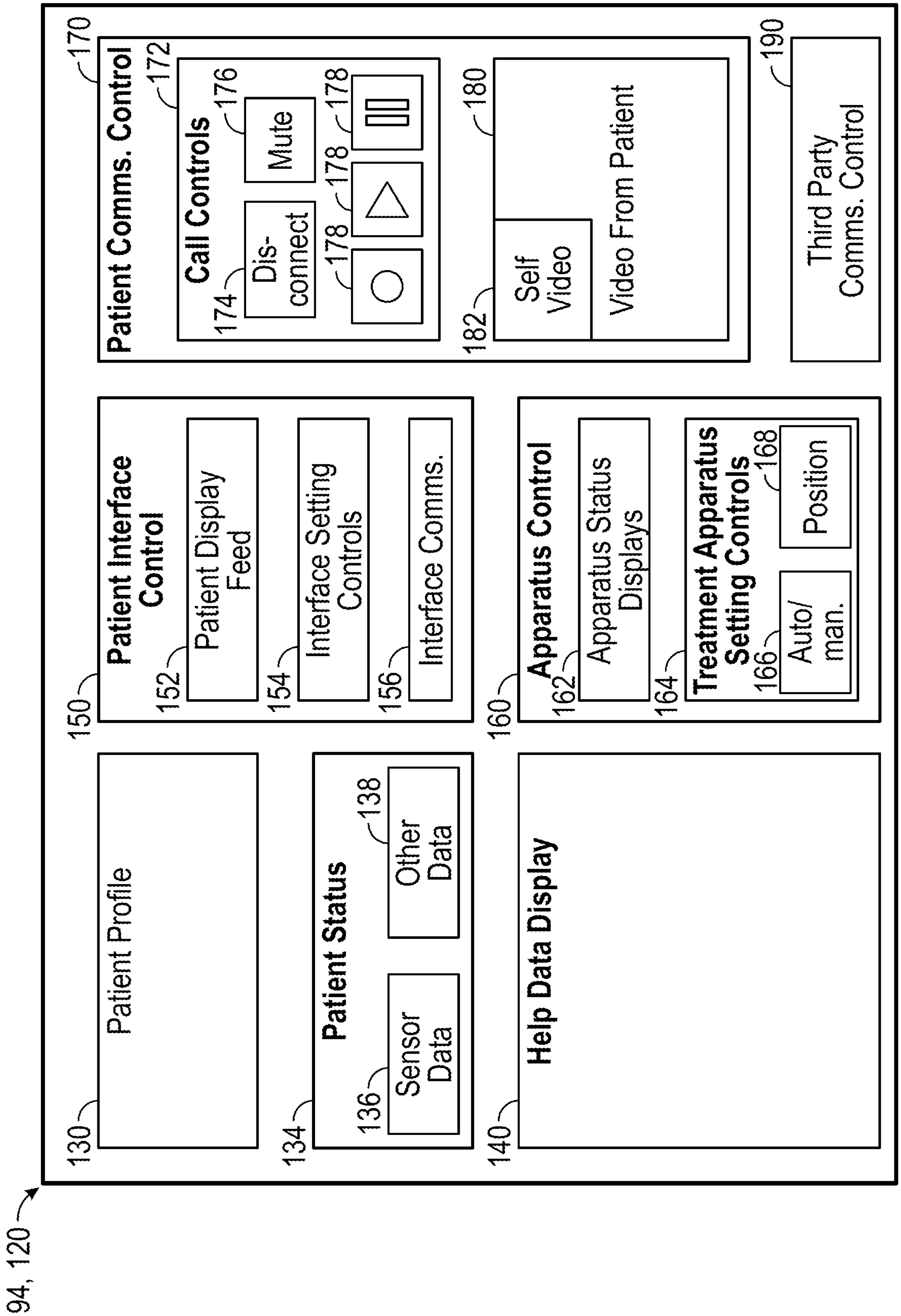

94, 120
130
Patient Profile
134
Patient Status
136
Sensor Data
138
Other Data
140
Help Data Display
150
Patient Interface Control
152
Patient Display Feed
154
Interface Setting Controls
156
Interface Comms.
160
Apparatus Control
162
Apparatus Status Displays
164
Treatment Apparatus Setting Controls
166
Auto/ man.
168
Position
170
Patient Comms. Control
172
Call Controls
174
Dis- connect
176
Mute
178
178
178
180
Video From Patient
182
Self Video
190
Third Party Comms. Control

FIG. 5

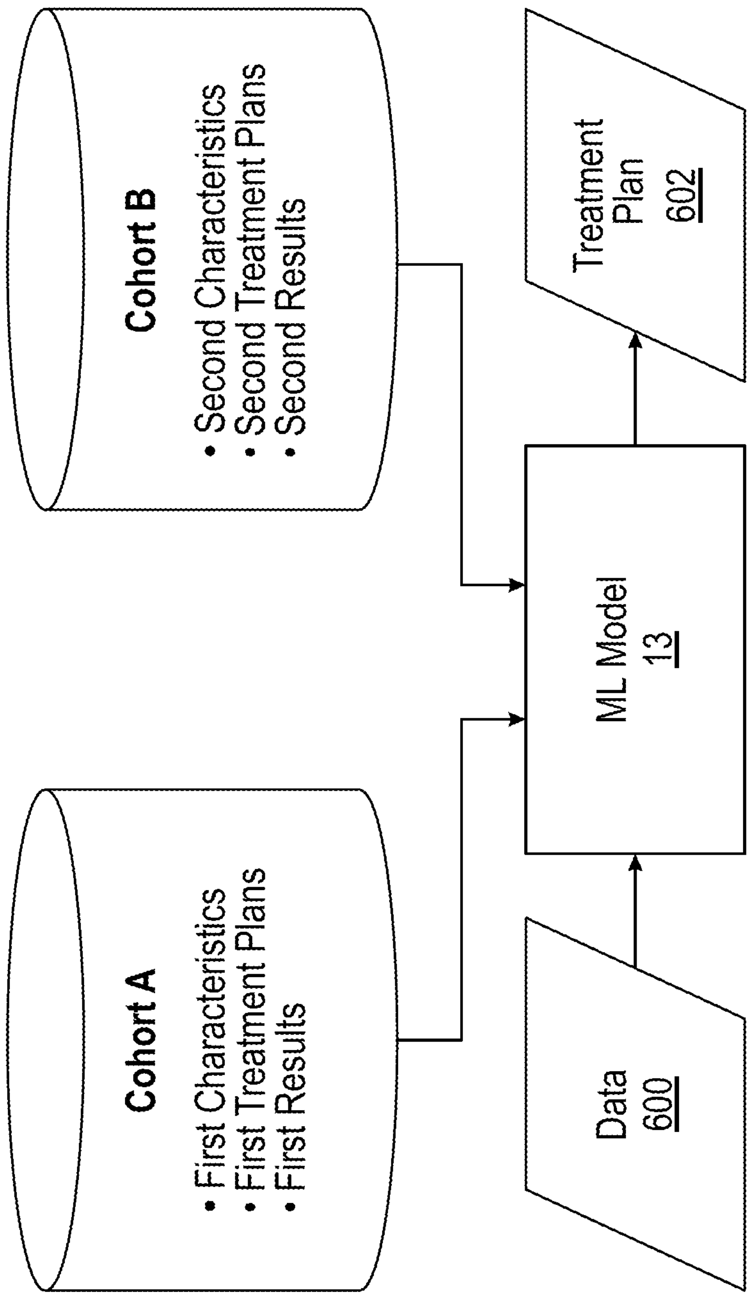

Cohort B
• Second Characteristics
• Second Treatment Plans
• Second Results
Cohort A
• First Characteristics
• First Treatment Plans
• First Results
Treatment Plan
602
ML Model
13
Data
600

FIG. 6

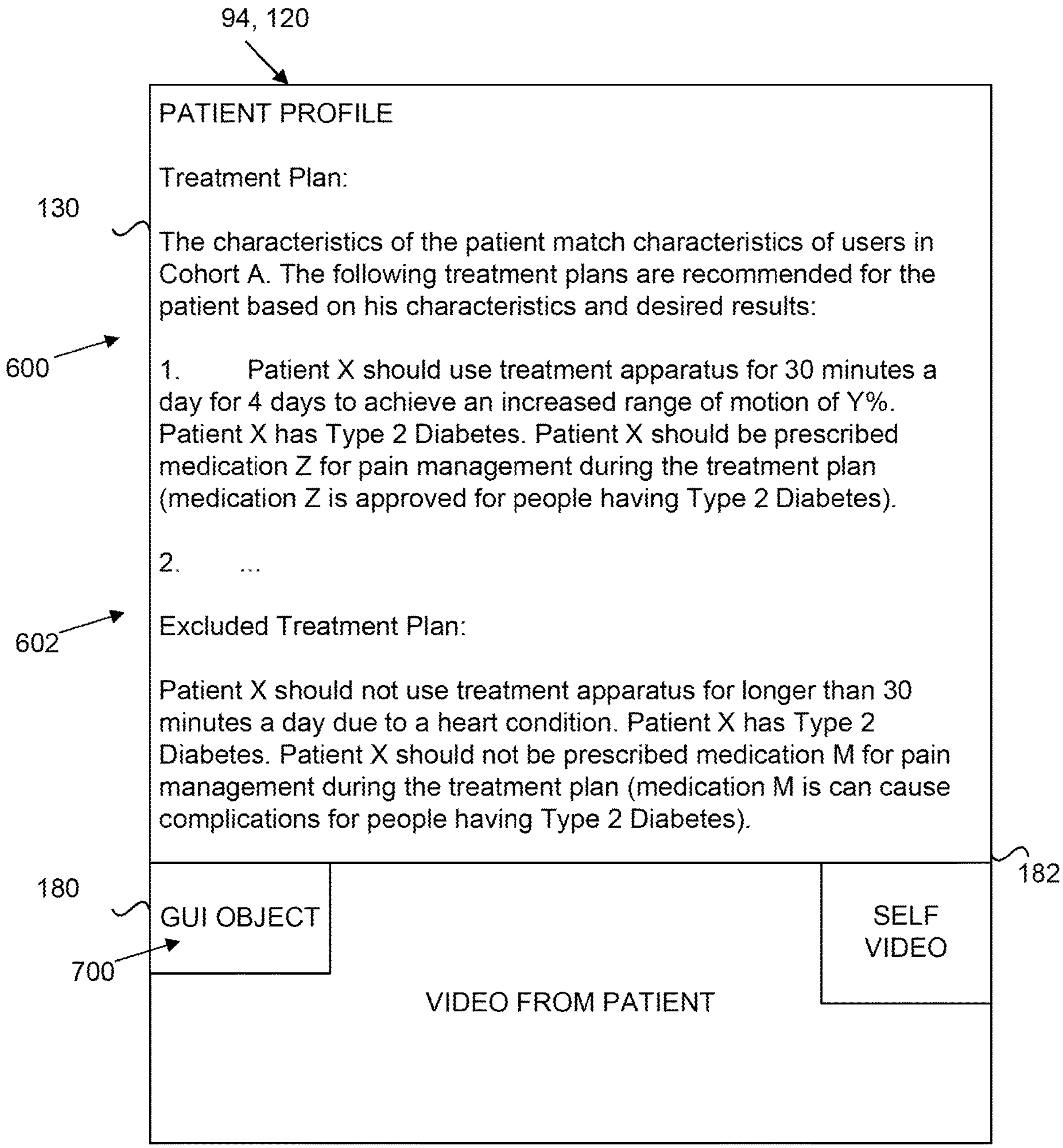

94, 120
PATIENT PROFILE
Treatment Plan:
130
The characteristics of the patient match characteristics of users in Cohort A. The following treatment plans are recommended for the patient based on his characteristics and desired results:
600
1. Patient X should use treatment apparatus for 30 minutes a day for 4 days to achieve an increased range of motion of Y%. Patient X has Type 2 Diabetes. Patient X should be prescribed medication Z for pain management during the treatment plan (medication Z is approved for people having Type 2 Diabetes).
2. ...
602
Excluded Treatment Plan:
Patient X should not use treatment apparatus for longer than 30 minutes a day due to a heart condition. Patient X has Type 2 Diabetes. Patient X should not be prescribed medication M for pain management during the treatment plan (medication M is can cause complications for people having Type 2 Diabetes).
180
GUI OBJECT
700
182
SELF VIDEO
VIDEO FROM PATIENT

FIG. 7

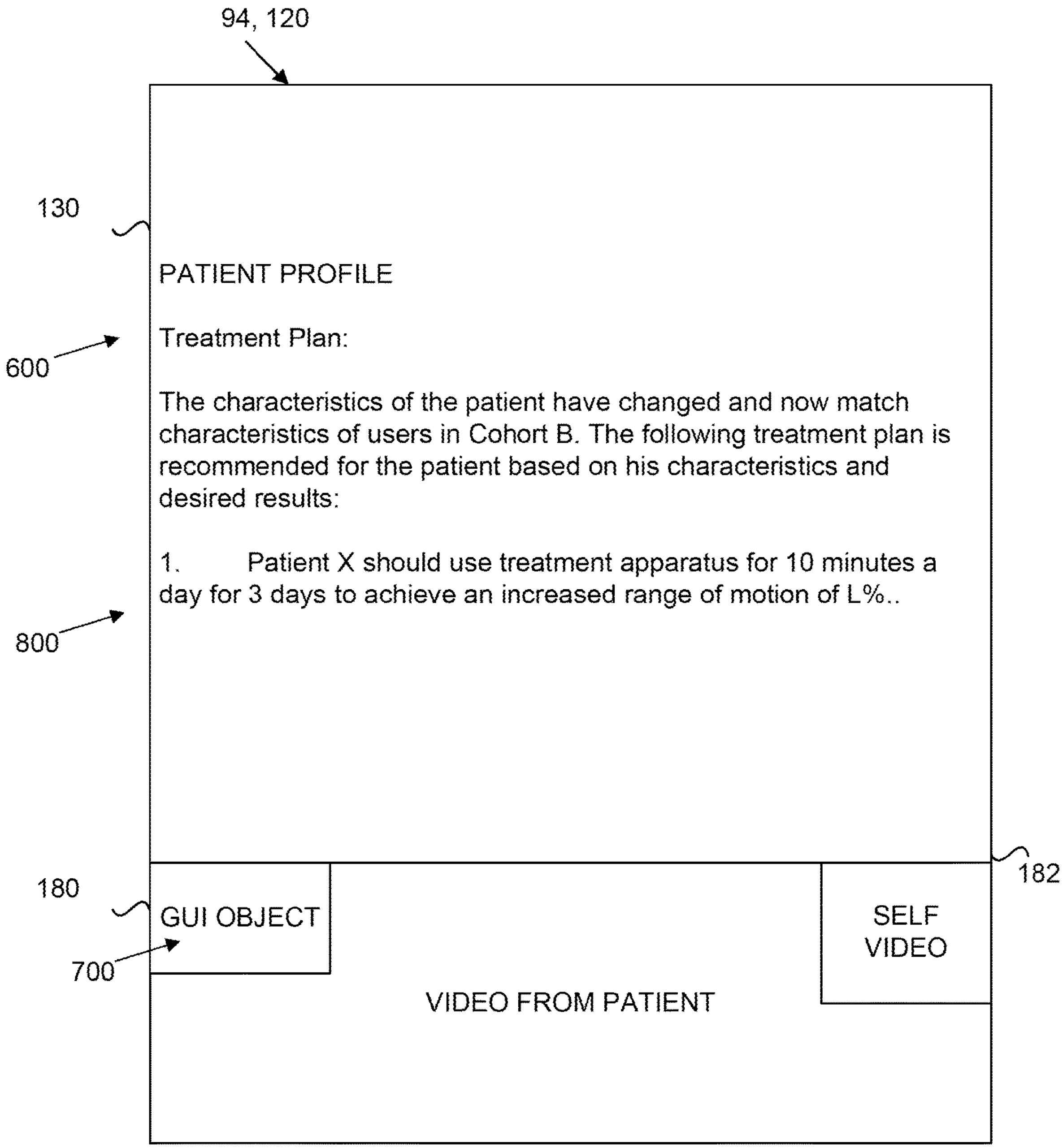

94, 120
130
PATIENT PROFILE
600
Treatment Plan:
The characteristics of the patient have changed and now match characteristics of users in Cohort B. The following treatment plan is recommended for the patient based on his characteristics and desired results:
1. Patient X should use treatment apparatus for 10 minutes a day for 3 days to achieve an increased range of motion of L%..
800
180
GUI OBJECT
700
VIDEO FROM PATIENT
SELF VIDEO
182

FIG. 8

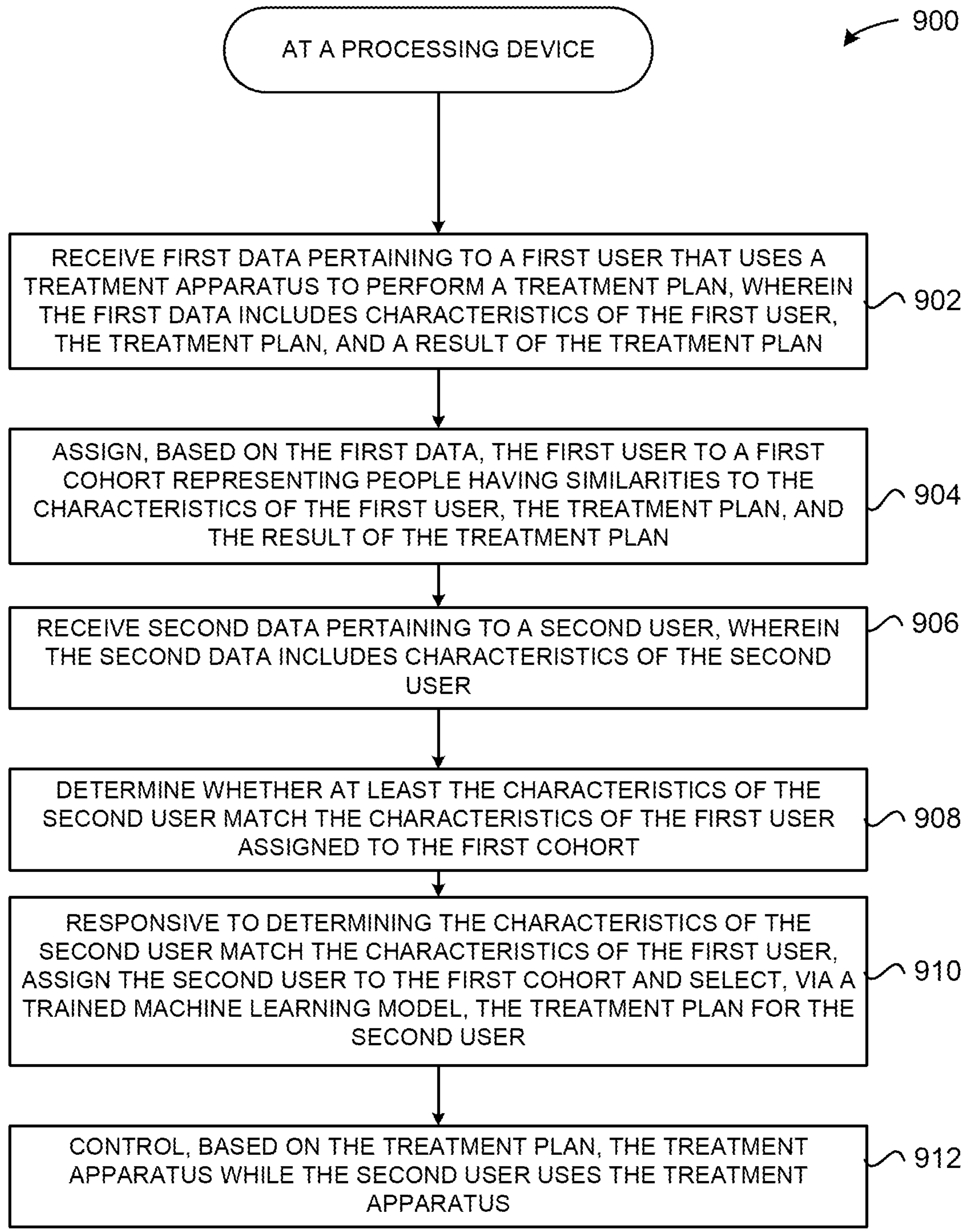

900
AT A PROCESSING DEVICE
RECEIVE FIRST DATA PERTAINING TO A FIRST USER THAT USES A TREATMENT APPARATUS TO PERFORM A TREATMENT PLAN, WHEREIN THE FIRST DATA INCLUDES CHARACTERISTICS OF THE FIRST USER, THE TREATMENT PLAN, AND A RESULT OF THE TREATMENT PLAN
902
ASSIGN, BASED ON THE FIRST DATA, THE FIRST USER TO A FIRST COHORT REPRESENTING PEOPLE HAVING SIMILARITIES TO THE CHARACTERISTICS OF THE FIRST USER, THE TREATMENT PLAN, AND THE RESULT OF THE TREATMENT PLAN
904
RECEIVE SECOND DATA PERTAINING TO A SECOND USER, WHEREIN THE SECOND DATA INCLUDES CHARACTERISTICS OF THE SECOND USER
906
DETERMINE WHETHER AT LEAST THE CHARACTERISTICS OF THE SECOND USER MATCH THE CHARACTERISTICS OF THE FIRST USER ASSIGNED TO THE FIRST COHORT
908
RESPONSIVE TO DETERMINING THE CHARACTERISTICS OF THE SECOND USER MATCH THE CHARACTERISTICS OF THE FIRST USER, ASSIGN THE SECOND USER TO THE FIRST COHORT AND SELECT, VIA A TRAINED MACHINE LEARNING MODEL, THE TREATMENT PLAN FOR THE SECOND USER
910
CONTROL, BASED ON THE TREATMENT PLAN, THE TREATMENT APPARATUS WHILE THE SECOND USER USES THE TREATMENT APPARATUS
912

FIG. 9

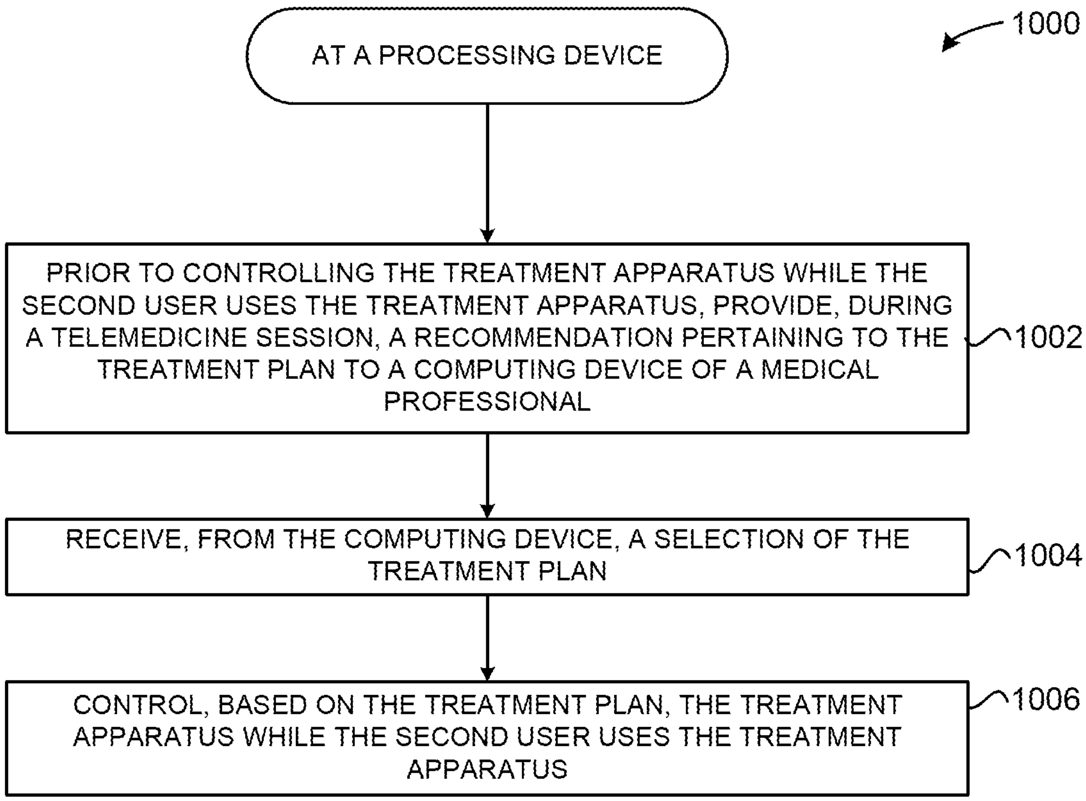

1000
AT A PROCESSING DEVICE
PRIOR TO CONTROLLING THE TREATMENT APPARATUS WHILE THE SECOND USER USES THE TREATMENT APPARATUS, PROVIDE, DURING A TELEMEDICINE SESSION, A RECOMMENDATION PERTAINING TO THE TREATMENT PLAN TO A COMPUTING DEVICE OF A MEDICAL PROFESSIONAL
1002
RECEIVE, FROM THE COMPUTING DEVICE, A SELECTION OF THE TREATMENT PLAN
1004
CONTROL, BASED ON THE TREATMENT PLAN, THE TREATMENT APPARATUS WHILE THE SECOND USER USES THE TREATMENT APPARATUS
1006

FIG. 10

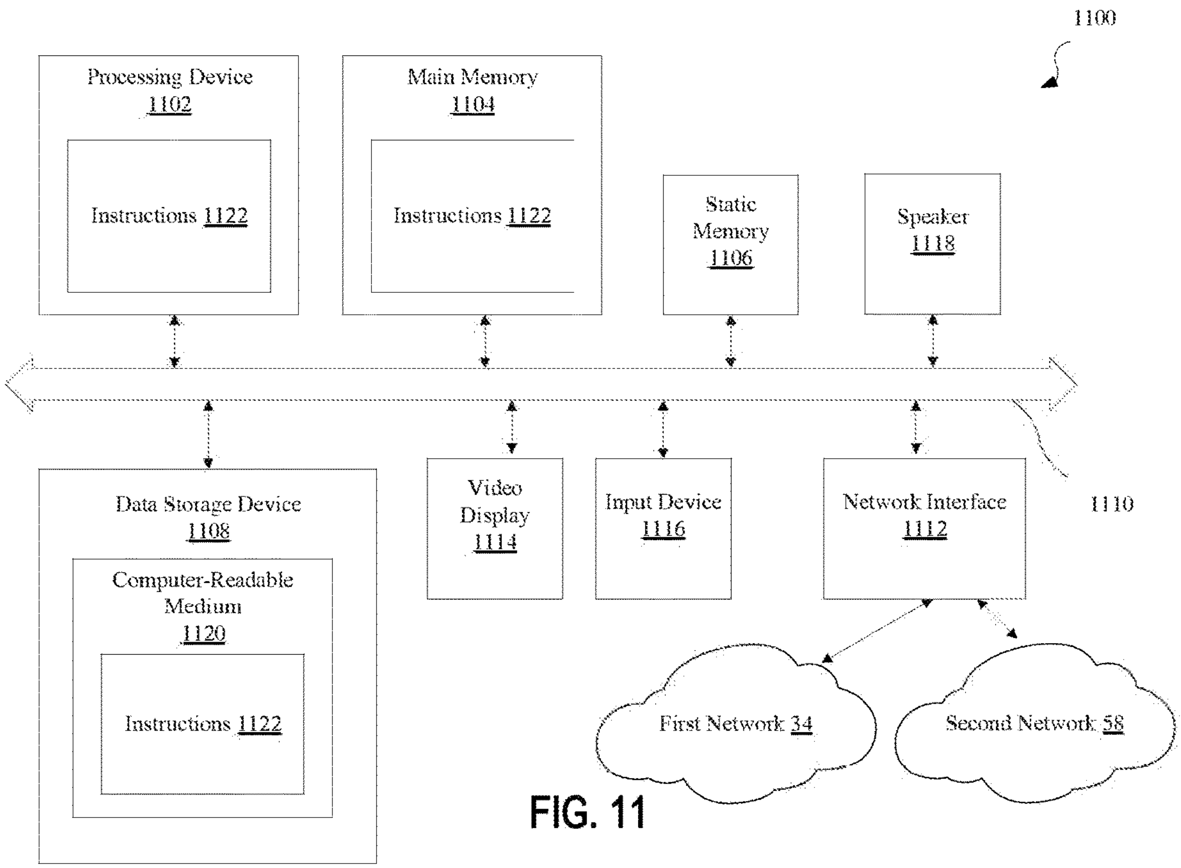

1100
Processing Device
1102
Instructions 1122
Main Memory
1104
Instructions 1122
Static
Memory
1106
Speaker
1118
Data Storage Device
1108
Computer-Readable
Medium
1120
Instructions 1122
Video
Display
1114
Input Device
1116
Network Interface
1112
1110
First Network 34
Second Network 58

FIG. 11

AUGMENTED REALITY PLACEMENT OF GONIOMETER OR OTHER SENSORS

CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 17/021,895, filed Sep. 15, 2020, titled "Telemedicine for Orthopedic Treatment," which claims priority to and the benefit of U.S. Provisional Patent Application Ser. No. 62/910,232, filed Oct. 3, 2019, titled "Telemedicine for Orthopedic Treatment," the entire disclosures of which are hereby incorporated by reference for all purposes.

BACKGROUND

Remote medical assistance, also referred to, inter alia, as remote medicine, telemedicine, telemed, telmed, tel-med, or telehealth, is an at least two-way communication between a healthcare provider or providers, such as a physician or a physical therapist, and a patient using audio and/or audiovisual and/or other sensorial or perceptive (e.g., without limitation, gesture recognition, gesture control, touchless user interfaces (TUIs), kinetic user interfaces (KUIs), tangible user interfaces, wired gloves, depth-aware cameras, stereo cameras, and gesture-based controllers, tactile, gustatory, haptic, pressure-sensing-based or electromagnetic (e.g., neurostimulation) communications (e.g., via a computer, a smartphone, or a tablet). Telemedicine may aid a patient in performing various aspects of a rehabilitation regimen for a body part. The patient may use a patient interface in communication with an assistant interface for receiving the remote medical assistance via audio, visual, audiovisual, or other communications described elsewhere herein. Any reference herein to any particular sensorial modality shall be understood to include and to disclose by implication a different one or more sensory modalities.

Telemedicine is an option for healthcare providers to communicate with patients and provide patient care when the patients do not want to or cannot easily go to the healthcare providers' offices. Telemedicine, however, has substantive limitations as the healthcare providers cannot conduct physical examinations of the patients. Rather, the healthcare providers must rely on verbal communication and/or limited remote observation of the patients.

SUMMARY

An aspect of the disclosed embodiments includes a system for positioning one or more sensors on a user has an apparatus configured to be manipulated by the user to perform an exercise. The system has user sensors associated with the user and apparatus sensors associated with the apparatus. The system has treatment sensors, a processing device and a memory communicatively coupled to the processing device and including computer readable instructions, that when executed by the processing device, cause the processing device to: generate an enhanced environment representative of an environment; receive, from the apparatus sensors, apparatus data representative of a location of the apparatus in the environment; generate, from the apparatus data, an apparatus avatar in the enhanced environment; receive, from the user sensors, user data representative of a location of the user in the environment; generate, from the user data, a user avatar in the enhanced environment; receive, from the treatment sensors, treatment data representative of one or more locations of the treatment sensors in the environment; generate, from the treatment data, treatment sensor avatars in the enhanced environment; calculate, based on one or more of the apparatus data and the user data, a treatment location for each treatment sensor, wherein the treatment location is associated with an anatomical structure of a user; and generate, based on the treatment location and treatment data, instruction data representing an instruction for positioning the treatment sensors at the treatment location.

Another aspect of the disclosed embodiments includes a method for positioning one or more sensors on a user, comprises generating an enhanced environment associated with an environment. The method comprises receiving, from apparatus sensors, apparatus data representative of a location of the apparatus in the environment. The method comprises generating, from the apparatus data, an apparatus avatar in the enhanced environment. The method comprises receiving, from user sensors, user data representative of a location of the user in the environment. The method comprises generating, from the user data, a user avatar in the enhanced environment. The method comprises receiving, from treatment sensors, treatment data representative of a location the treatment sensors in the environment. The method comprises generating, from the treatment data, treatment sensor avatars in the enhanced environment. The method comprises calculating, based on one or more of the environment data, apparatus data, and user data, a treatment location for each treatment sensor. The method comprises generating, based on the treatment location and treatment data, instruction data representative of the treatment sensors relative to the user.

Another aspect of the disclosed embodiments includes a tangible, non-transitory computer-readable medium stores instructions that, when executed, cause a processing device to perform any of the methods, operations, or steps described herein.

Another aspect of the disclosed embodiments includes a system that includes a processing device and a memory communicatively coupled to the processing device and capable of storing instructions. The processing device executes the instructions to perform any of the methods, operations, or steps described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosure is best understood from the following detailed description when read in conjunction with the accompanying drawings. It is emphasized that, according to common practice, the various features of the drawings are not to-scale. On the contrary, the dimensions of the various features are arbitrarily expanded or reduced for clarity.

For a detailed description of example embodiments, reference will now be made to the accompanying drawings in which:

FIG. **1** generally illustrates a block diagram of an embodiment of a computer implemented system for managing a treatment plan according to the principles of the present disclosure;

FIG. **2** generally illustrates a perspective view of an embodiment of a treatment apparatus according to the principles of the present disclosure;

FIG. **3** generally illustrates a perspective view of a pedal of the treatment apparatus of FIG. **2** according to the principles of the present disclosure;

FIG. **4** generally illustrates a perspective view of a person using the treatment apparatus of FIG. **2** according to the principles of the present disclosure;

FIG. **5** generally illustrates an example embodiment of an overview display of an assistant interface according to the principles of the present disclosure;

FIG. **6** generally illustrates an example block diagram of training a machine learning model to output, based on data pertaining to the patient, a treatment plan for the patient according to the principles of the present disclosure;

FIG. **7** generally illustrates an embodiment of an overview display of the assistant interface presenting recommended treatment plans and excluded treatment plans in real-time during a telemedicine session according to the principles of the present disclosure;

FIG. **8** generally illustrates an embodiment of the overview display of the assistant interface presenting, in near real-time during a telemedicine session, recommended treatment plans that have changed as a result of patient data changing according to the principles of the present disclosure;

FIG. **9** generally illustrates an example embodiment of a method for selecting, based on assigning a patient to a cohort, a treatment plan for the patient and controlling, based on the treatment plan, a treatment apparatus according to the principles of the present disclosure;

FIG. **10** generally illustrates an example embodiment of a method for presenting, during a telemedicine session, the recommended treatment plan to a healthcare professional according to the principles of the present disclosure; and

FIG. **11** generally illustrates an example computer system according to the principles of the present disclosure.

NOTATION AND NOMENCLATURE

Various terms are used to refer to particular system components. Different companies may refer to a component by different names—this document does not intend to distinguish between components that differ in name but not function. In the following discussion and in the claims, the terms "including" and "comprising" are used in an open-ended fashion, and thus should be interpreted to mean "including, but not limited to . . . " Also, the term "couple" or "couples" is intended to mean either an indirect or direct connection. Thus, if a first device couples to a second device, that connection may be through a direct connection or through an indirect connection via other devices and connections.

The terminology used herein is for the purpose of describing particular example embodiments only, and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

The terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections; however, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer, or section from another region, layer, or section. Terms such as "first," "second," and other numerical terms, when used herein, do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer, or section discussed below could be termed a second element, component, region, layer, or section without departing from the teachings of the example embodiments. The phrase "at least one of," when used with a list of items, means that different combinations of one or more of the listed items may be used, and only one item in the list may be needed. For example, "at least one of: A, B, and C" includes any of the following combinations: A, B, C, A and B, A and C, B and C, and A and B and C. In another example, the phrase "one or more" when used with a list of items means there may be one item or any suitable number of items exceeding one.

Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper," "top," "bottom," "inside," "outside," "contained within," "superimposing upon," and the like, may be used herein. These spatially relative terms can be used for ease of description to describe one element's or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms may also be intended to encompass different orientations of the device in use, or operation, in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptions used herein interpreted accordingly.

A "treatment plan" may include one or more treatment protocols, and each treatment protocol includes one or more treatment sessions. Each treatment session comprises several session periods, with each session period including a particular exercise for treating the body part of the patient. For example, a treatment plan for post-operative rehabilitation after a knee surgery may include an initial treatment protocol with twice daily stretching sessions for the first 3 days after surgery and a more intensive treatment protocol with active exercise sessions performed 4 times per day starting 4 days after surgery. A treatment plan may also include information pertaining to a medical procedure to perform on the patient, a treatment protocol for the patient using a treatment apparatus, a diet regimen for the patient, a medication regimen for the patient, a sleep regimen for the patient, additional regimens, or some combination thereof.

The terms telemedicine, telehealth, telemed, teletherapeutic, etc. may be used interchangeably herein.

The term "optimal treatment plan" may refer to optimizing a treatment plan based on a certain parameter or factors or combinations of more than one parameter or factor, such as, but not limited to, a measure of benefit which one or more exercise regimens provide to users, one or more probabilities of users complying with one or more exercise regimens, an amount, quality or other measure of sleep associated with the user, information pertaining to a diet of the user, information pertaining to an eating schedule of the user, information pertaining to an age of the user, information pertaining to a sex of the user, information pertaining to a gender of the user, an indication of a mental state of the user, information pertaining to a genetic condition of the user, information pertaining to a disease state of the user, an indication of an energy level of the user, information pertaining to a microbiome from one or more locations on or in the user (e.g., skin, scalp, digestive tract, vascular system, etc.), or some combination thereof.

As used herein, the term healthcare professional may include a medical professional (e.g., such as a doctor, a nurse, a therapist, and the like), an exercise professional (e.g., such as a coach, a trainer, a nutritionist, and the like), or another professional sharing at least one of medical and exercise attributes (e.g., such as an exercise physiologist, a physical therapist, an occupational therapist, and the like). As used herein, and without limiting the foregoing, a "healthcare provider" may be a human being, a robot, a virtual assistant, a virtual assistant in virtual and/or augmented reality, or an artificially intelligent entity, such entity including a software program, integrated software and hardware, or hardware alone.

Real-time may refer to less than or equal to 2 seconds. Near real-time may refer to any interaction of a sufficiently short time to enable two individuals to engage in a dialogue via such user interface, and will preferably but not determinatively be less than 10 seconds but greater than 2 seconds.

Any of the systems and methods described in this disclosure may be used in connection with rehabilitation. Rehabilitation may be directed at cardiac rehabilitation, rehabilitation from stroke, multiple sclerosis, Parkinson's disease, myasthenia gravis, Alzheimer's disease, any other neurodegenative or neuromuscular disease, a brain injury, a spinal cord injury, a spinal cord disease, a joint injury, a joint disease, post-surgical recovery, or the like. Rehabilitation can further involve muscular contraction in order to improve blood flow and lymphatic flow, engage the brain and nervous system to control and affect a traumatized area to increase the speed of healing, reverse or reduce pain (including arthralgias and myalgias), reverse or reduce stiffness, recover range of motion, encourage cardiovascular engagement to stimulate the release of pain-blocking hormones or to encourage highly oxygenated blood flow to aid in an overall feeling of well-being. Rehabilitation may be provided for individuals of average weight in reasonably good physical condition having no substantial deformities, as well as for individuals more typically in need of rehabilitation, such as those who are elderly, obese, subject to disease processes, injured and/or who have a severely limited range of motion. Unless expressly stated otherwise, is to be understood that rehabilitation includes prehabilitation (also referred to as "pre-habilitation" or "prehab"). Prehabilitation may be used as a preventative procedure or as a pre-surgical or pre-treatment procedure. Prehabilitation may include any action performed by or on a patient (or directed to be performed by or on a patient, including, without limitation, remotely or distally through telemedicine) to, without limitation, prevent or reduce a likelihood of injury (e.g., prior to the occurrence of the injury); improve recovery time subsequent to surgery; improve strength subsequent to surgery; or any of the foregoing with respect to any non-surgical clinical treatment plan to be undertaken for the purpose of ameliorating or mitigating injury, dysfunction, or other negative consequence of surgical or non-surgical treatment on any external or internal part of a patient's body. For example, a mastectomy may require prehabilitation to strengthen muscles or muscle groups affected directly or indirectly by the mastectomy. As a further non-limiting example, the removal of an intestinal tumor, the repair of a hernia, open-heart surgery or other procedures performed on internal organs or structures, whether to repair those organs or structures, to excise them or parts of them, to treat them, etc., can require cutting through, dissecting and/or harming numerous muscles and muscle groups in or about, without limitation, the skull or face, the abdomen, the ribs and/or the thoracic cavity, as well as in or about all joints and appendages. Prehabilitation can improve a patient's speed of recovery, measure of quality of life, level of pain, etc. in all the foregoing procedures. In one embodiment of prehabilitation, a pre-surgical procedure or a pre-non-surgical-treatment may include one or more sets of exercises for a patient to perform prior to such procedure or treatment. Performance of the one or more sets of exercises may be required in order to qualify for an elective surgery, such as a knee replacement. The patient may prepare an area of his or her body for the surgical procedure by performing the one or more sets of exercises, thereby strengthening muscle groups, improving existing muscle memory, reducing pain, reducing stiffness, establishing new muscle memory, enhancing mobility (i.e., improve range of motion), improving blood flow, and/or the like.

The phrase, and all permutations of the phrase, "respective measure of benefit with which one or more exercise regimens may provide the user" (e.g., "measure of benefit," "respective measures of benefit," "measures of benefit," "measure of exercise regimen benefit," "exercise regimen benefit measurement," etc.) may refer to one or more measures of benefit with which one or more exercise regimens may provide the user.

The term "enhanced reality" or "enhanced environment" may include a user experience comprising one or more of an interaction with a computer, augmented reality, virtual reality, mixed reality, immersive reality, or a combination of the foregoing (e.g., immersive augmented reality, mixed augmented reality, virtual and augmented immersive reality, and the like).

The term "augmented reality" may refer, without limitation, to an interactive user experience that provides an enhanced environment that combines elements of a real-world environment with computer-generated components perceivable by the user.

The term "virtual reality" may refer, without limitation, to a simulated interactive user experience that provides an enhanced environment perceivable by the user and wherein such enhanced environment may be similar to or different from a real-world environment.

The term "mixed reality" may refer to an interactive user experience that combines aspects of augmented reality with aspects of virtual reality to provide a mixed reality environment perceivable by the user.

The term "immersive reality" may refer to a simulated interactive user experienced using virtual and/or augmented reality images, sounds, and other stimuli to immerse the user, to a specific extent possible (e.g., partial immersion or total immersion), in the simulated interactive experience. For example, in some embodiments, to the specific extent possible, the user experiences one or more aspects of the immersive reality as naturally as the user typically experiences corresponding aspects of the real-world. Additionally, or alternatively, an immersive reality experience may include actors, a narrative component, a theme (e.g., an entertainment theme or other suitable theme), and/or other suitable features of components.

The term "body halo" may refer to a hardware component or components, wherein such component or components may include one or more platforms, one or more body supports or cages, one or more chairs or seats, one or more back supports, one or more leg or foot engaging mechanisms, one or more arm or hand engaging mechanisms, one or more neck or head engaging mechanisms, other suitable hardware components, or a combination thereof.

As used herein, the term "enhanced environment" may refer to an enhanced environment in its entirety, at least one aspect of the enhanced environment, more than one aspect of the enhanced environment, or any suitable number of aspects of the enhanced environment.

DETAILED DESCRIPTION

The following discussion is directed to various embodiments of the present disclosure. Although one or more of these embodiments may be preferred, the embodiments disclosed should not be interpreted, or otherwise used, as limiting the scope of the disclosure, including the claims. In addition, one skilled in the art will understand that the following description has broad application, and the discussion of any embodiment is meant only to be exemplary of that embodiment, and not intended to intimate that the scope of the disclosure, including the claims, is limited to that embodiment.

Determining a treatment plan for a patient having certain characteristics (e.g., vital-sign or other measurements; performance; demographic; psychographic; geographic; diagnostic; measurement- or test-based; medically historic; etiologic; cohort-associative; differentially diagnostic; surgical, physically therapeutic, psychographic, pharmacologic and other treatment(s) recommended; etc.) may be a technically challenging problem. For example, a multitude of information may be considered when determining a treatment plan, which may result in inefficiencies and inaccuracies in the treatment plan selection process. In a rehabilitative setting, some of the multitude of information considered may include characteristics of the patient such as personal information, performance information, and measurement information. The personal information may include, e.g., demographic, psychographic or other information, such as an age, a weight, a gender, a height, a body mass index, a medical condition, a familial medication history, an injury, a medical procedure, a medication prescribed, or some combination thereof. The performance information may include, e.g., an elapsed time of using a treatment apparatus, an amount of force exerted on a portion of the treatment apparatus, a range of motion achieved on the treatment apparatus, a movement speed of a portion of the treatment apparatus, an indication of a plurality of pain levels using the treatment apparatus, or some combination thereof. The measurement information may include, e.g., a vital sign, a respiration rate, a heartrate, a temperature, a blood pressure, or some combination thereof. It may be desirable to process the characteristics of a multitude of patients, the treatment plans performed for those patients, and the results of the treatment plans for those patients.

Further, another technical problem may involve distally treating, via a computing device during a telemedicine session, a patient from a location different than a location at which the patient is located. An additional technical problem is controlling or enabling, from the different location, the control of a treatment apparatus used by the patient's location. Oftentimes, when a patient undergoes rehabilitative surgery (e.g., knee surgery), a healthcare provider or other healthcare professional may prescribe a treatment apparatus to the patient to use to perform a treatment protocol at their residence or at any mobile location or temporary domicile. A healthcare professional may refer to a doctor, physician assistant, nurse, chiropractor, dentist, physical therapist, acupuncturist, physical trainer, or the like. A healthcare professional may refer to any person with a credential, license, degree, or the like in the field of medicine, physical therapy, rehabilitation, or the like.

Since the physical therapist or other healthcare professional is located in a location different from the patient and the treatment apparatus, it may be technically challenging for the physical therapist or other healthcare professional to monitor the patient's actual progress (as opposed to relying on the patient's word about their progress) in using the treatment apparatus, modify the treatment plan according to the patient's progress, adapt the treatment apparatus to the personal characteristics of the patient as the patient performs the treatment plan, and the like.

Accordingly, embodiments of the present disclosure pertain to using artificial intelligence and/or machine learning to assign patients to cohorts and to dynamically control a treatment apparatus based on the assignment during an adaptive telemedical session. In some embodiments, numerous treatment apparatuses may be provided to patients. The treatment apparatuses may be used by the patients to perform treatment plans in their residences, at a gym, at a rehabilitative center, at a hospital, or any suitable location, including permanent or temporary domiciles. In some embodiments, the treatment apparatuses may be communicatively coupled to a server. Characteristics of the patients may be collected before, during, and/or after the patients perform the treatment plans. For example, the personal information, the performance information, and the measurement information may be collected before, during, and/or after the person performs the treatment plans. The results (e.g., improved performance or decreased performance) of performing each exercise may be collected from the treatment apparatus throughout the treatment plan and after the treatment plan is performed. The parameters, settings, configurations, etc. (e.g., position of pedal, amount of resistance, etc.) of the treatment apparatus may be collected before, during, and/or after the treatment plan is performed.

Each characteristic of the patient, each result, and each parameter, setting, configuration, etc. may be timestamped and may be correlated with a particular step in the treatment plan. Such a technique may enable determining which steps in the treatment plan lead to desired results (e.g., improved muscle strength, range of motion, etc.) and which steps lead to diminishing returns (e.g., continuing to exercise after 3 minutes actually delays or harms recovery).

Data may be collected from the treatment apparatuses and/or any suitable computing device (e.g., computing devices where personal information is entered, such as a clinician interface or patient interface) over time as the patients use the treatment apparatuses to perform the various treatment plans. The data that may be collected may include the characteristics of the patients, the treatment plans performed by the patients, and the results of the treatment plans.

In some embodiments, the data may be processed to group certain people into cohorts. The people may be grouped by people having certain or selected similar characteristics, treatment plans, and results of performing the treatment plans. For example, athletic people having no medical conditions who perform a treatment plan (e.g., use the treatment apparatus for 30 minutes a day 5 times a week for 3 weeks) and who fully recover may be grouped into a first cohort. Older people who are classified obese and who perform a treatment plan (e.g., use the treatment plan for 10 minutes a day 3 times a week for 4 weeks) and who improve their range of motion by 75 percent may be grouped into a second cohort.

In some embodiments, an artificial intelligence engine may include one or more machine learning models that are trained using the cohorts. For example, the one or more machine learning models may be trained to receive an input of characteristics of a new patient and to output a treatment plan for the patient that results in a desired result. The machine learning models may match a pattern between the characteristics of the new patient and at least one patient of the patients included in a particular cohort. When a pattern is matched, the machine learning models may assign the new patient to the particular cohort and select the treatment plan associated with the at least one patient. The artificial intelligence engine may be configured to control, distally and based on the treatment plan, the treatment apparatus while the new patient uses the treatment apparatus to perform the treatment plan.

As may be appreciated, the characteristics of the new patient may change as the new patient uses the treatment apparatus to perform the treatment plan. For example, the performance of the patient may improve quicker than expected for people in the cohort to which the new patient is currently assigned. Accordingly, the machine learning models may be trained to dynamically reassign, based on the changed characteristics, the new patient to a different cohort that includes people having characteristics similar to the now-changed characteristics as the new patient. For example, a clinically obese patient may lose weight and no longer meet the weight criterion for the initial cohort, result in the patient's being reassigned to a different cohort with a different weight criterion. A different treatment plan may be selected for the new patient, and the treatment apparatus may be controlled, distally and based on the different treatment plan, the treatment apparatus while the new patient uses the treatment apparatus to perform the treatment plan. Such techniques may provide the technical solution of distally controlling a treatment apparatus. Further, the techniques may lead to faster recovery times and/or better results for the patients because the treatment plan that most accurately fits their characteristics is selected and implemented, in real-time, at any given moment. "Real-time" may also refer to near real-time, which may be less than 10 seconds or any reasonably proximate difference between two different times. As described herein, the term "results" may refer to medical results or medical outcomes. Results and outcomes may refer to responses to medical actions.

Depending on what result is desired, the artificial intelligence engine may be trained to output several treatment plans. For example, one result may include recovering to a threshold level (e.g., 75% range of motion) in a fastest amount of time, while another result may include fully recovering (e.g., 100% range of motion) regardless of the amount of time. The data obtained from the patients and sorted into cohorts may indicate that a first treatment plan provides the first result for people with characteristics similar to the patient's, and that a second treatment plan provides the second result for people with characteristics similar to the patient.

Further, the artificial intelligence engine may also be trained to output treatment plans that are not optimal or sub-optimal or even inappropriate (all referred to, without limitation, as "excluded treatment plans") for the patient. For example, if a patient has high blood pressure, a particular exercise may not be approved or suitable for the patient as it may put the patient at unnecessary risk or even induce a hypertensive crisis and, accordingly, that exercise may be flagged in the excluded treatment plan for the patient.

In some embodiments, the treatment plans and/or excluded treatment plans may be presented, during a telemedicine or telehealth session, to a healthcare professional. The healthcare professional may select a particular treatment plan for the patient to cause that treatment plan to be transmitted to the patient and/or to control, based on the treatment plan, the treatment apparatus. In some embodiments, to facilitate telehealth or telemedicine applications, including remote diagnoses, determination of treatment plans and rehabilitative and/or pharmacologic prescriptions, the artificial intelligence engine may receive and/or operate distally from the patient and the treatment apparatus. In such cases, the recommended treatment plans and/or excluded treatment plans may be presented simultaneously with a video of the patient in real-time or near real-time during a telemedicine or telehealth session on a user interface of a computing device of a healthcare professional. The video may also be accompanied by audio, text and other multimedia information and/or other sensorial or perceptive (e.g., tactile, gustatory, haptic, pressure-sensing-based or electromagnetic (e.g., nurostimulation). Real-time may refer to less than or equal to 2 seconds. Near real-time may refer to any interaction of a sufficiently short time to enable two individuals to engage in a dialogue via such user interface, and will generally be less than 10 seconds (or any suitable proximate difference between two different times) but greater than 2 seconds.

Presenting the treatment plans generated by the artificial intelligence engine concurrently with a presentation of the patient video may provide an enhanced user interface because the healthcare professional may continue to visually and/or otherwise communicate with the patient while also reviewing the treatment plans on the same user interface. The enhanced user interface may improve the healthcare professional's experience using the computing device and may encourage the healthcare professional to reuse the user interface. Such a technique may also reduce computing resources (e.g., processing, memory, network) because the healthcare professional does not have to switch to another user interface screen to enter a query for a treatment plan to recommend based on the characteristics of the patient. The artificial intelligence engine provides, dynamically on the fly, the treatment plans and excluded treatment plans.

In some embodiments, the treatment apparatus may be adaptive and/or personalized because its properties, configurations, and positions may be adapted to the needs of a particular patient. For example, the pedals may be dynamically adjusted on the fly (e.g., via a telemedicine session or based on programmed configurations in response to certain measurements being detected) to increase or decrease a range of motion to comply with a treatment plan designed for the user. In some embodiments, a healthcare professional may adapt, remotely during a telemedicine session, the treatment apparatus to the needs of the patient by causing a control instruction to be transmitted from a server to treatment apparatus. Such adaptive nature may improve the results of recovery for a patient, furthering the goals of personalized medicine, and enabling personalization of the treatment plan on a per-individual basis.

FIG. **1** shows a block diagram of a computer-implemented system **10**, hereinafter called "the system" for managing a treatment plan. Managing the treatment plan may include using an artificial intelligence engine to recommend treatment plans and/or provide excluded treatment plans that should not be recommended to a patient.

The system **10** also includes a server **30** configured to store and to provide data related to managing the treatment plan. The server **30** may include one or more computers and may take the form of a distributed and/or virtualized computer or computers. The server **30** also includes a first communication interface **32** configured to communicate with the clinician interface **20** via a first network **34**. In some embodiments, the first network **34** may include wired and/or wireless network connections such as Wi-Fi, Bluetooth, ZigBee, Near-Field Communications (NFC), cellular data network, etc. The server **30** includes a first processor **36** and a first machine-readable storage memory **38**, which may be called a "memory" for short, holding first instructions **40** for performing the various actions of the server **30** for execution by the first processor **36**. The server **30** is configured to store data regarding the treatment plan. For example, the memory **38** includes a system data store **42** configured to hold system data, such as data pertaining to treatment plans for treating one or more patients. The server **30** is also configured to store data regarding performance by a patient in following a treatment plan. For example, the memory **38** includes a patient data store **44** configured to hold patient data, such as data pertaining to the one or more patients, including data representing each patient's performance within the treatment plan.

In addition, the characteristics (e.g., personal, performance, measurement, etc.) of the people, the treatment plans followed by the people, the level of compliance with the treatment plans, and the results of the treatment plans may use correlations and other statistical or probabilistic measures to enable the partitioning of or to partition the treatment plans into different patient cohort-equivalent databases in the patient data store **44**. For example, the data for a first cohort of first patients having a first similar injury, a first similar medical condition, a first similar medical procedure performed, a first treatment plan followed by the first patient, and a first result of the treatment plan may be stored in a first patient database. The data for a second cohort of second patients having a second similar injury, a second similar medical condition, a second similar medical procedure performed, a second treatment plan followed by the second patient, and a second result of the treatment plan may be stored in a second patient database. Any single characteristic or any combination of characteristics may be used to separate the cohorts of patients. In some embodiments, the different cohorts of patients may be stored in different partitions or volumes of the same database. There is no specific limit to the number of different cohorts of patients allowed, other than as limited by mathematical combinatoric and/or partition theory.

This characteristic data, treatment plan data, and results data may be obtained from numerous treatment apparatuses and/or computing devices over time and stored in the database **44**. The characteristic data, treatment plan data, and results data may be correlated in the patient-cohort databases in the patient data store **44**. The characteristics of the people may include personal information, performance information, and/or measurement information.

In addition to the historical information about other people stored in the patient cohort-equivalent databases, real-time or near-real-time information based on the current patient's characteristics about a current patient being treated may be stored in an appropriate patient cohort-equivalent database. The characteristics of the patient may be determined to match or be similar to the characteristics of another person in a particular cohort (e.g., cohort A) and the patient may be assigned to that cohort.

In some embodiments, the server **30** may execute an artificial intelligence (AI) engine **11** that uses one or more machine learning models **13** to perform at least one of the embodiments disclosed herein. The server **30** may include a training engine **9** capable of generating the one or more machine learning models **13**. The machine learning models **13** may be trained to assign people to certain cohorts based on their characteristics, select treatment plans using real-time and historical data correlations involving patient cohort-equivalents, and control a treatment apparatus **70**, among other things. The one or more machine learning models **13** may be generated by the training engine **9** and may be implemented in computer instructions executable by one or more processing devices of the training engine **9** and/or the servers **30**. To generate the one or more machine learning models **13**, the training engine **9** may train the one or more machine learning models **13**. The one or more machine learning models **13** may be used by the artificial intelligence engine **11**.

The training engine **9** may be a rackmount server, a router computer, a personal computer, a portable digital assistant, a smartphone, a laptop computer, a tablet computer, a netbook, a desktop computer, an Internet of Things (IoT) device, any other desired computing device, or any combination of the above. The training engine **9** may be cloud-based or a real-time software platform, and it may include privacy software or protocols, and/or security software or protocols.

To train the one or more machine learning models **13**, the training engine **9** may use a training data set of a corpus of the characteristics of the people that used the treatment apparatus **70** to perform treatment plans, the details (e.g., treatment protocol including exercises, amount of time to perform the exercises, how often to perform the exercises, a schedule of exercises, parameters/configurations/settings of the treatment apparatus **70** throughout each step of the treatment plan, etc.) of the treatment plans performed by the people using the treatment apparatus **70**, and the results of the treatment plans performed by the people. The one or more machine learning models **13** may be trained to match patterns of characteristics of a patient with characteristics of other people in assigned to a particular cohort. The term "match" may refer to an exact match, a correlative match, a substantial match, etc. The one or more machine learning models **13** may be trained to receive the characteristics of a patient as input, map the characteristics to characteristics of people assigned to a cohort, and select a treatment plan from that cohort. The one or more machine learning models **13** may also be trained to control, based on the treatment plan, the machine learning apparatus **70**.

Different machine learning models **13** may be trained to recommend different treatment plans for different desired results. For example, one machine learning model may be trained to recommend treatment plans for most effective recovery, while another machine learning model may be trained to recommend treatment plans based on speed of recovery.

Using training data that includes training inputs and corresponding target outputs, the one or more machine learning models **13** may refer to model artifacts created by the training engine **9**. The training engine **9** may find patterns in the training data wherein such patterns map the training input to the target output, and generate the machine learning models **13** that capture these patterns. In some embodiments, the artificial intelligence engine **11**, the database **33**, and/or the training engine **9** may reside on another component (e.g., assistant interface **94**, clinician interface **20**, etc.) depicted in FIG. **1**.

The one or more machine learning models **13** may comprise, e.g., a single level of linear or non-linear operations (e.g., a support vector machine [SVM]) or the machine learning models **13** may be a deep network, i.e., a machine learning model comprising multiple levels of non-linear operations. Examples of deep networks are neural networks including generative adversarial networks, convolutional neural networks, recurrent neural networks with one or more hidden layers, and fully connected neural networks (e.g., each neuron may transmit its output signal to the input of the remaining neurons, as well as to itself). For example, the machine learning model may include numerous layers and/or hidden layers that perform calculations (e.g., dot products) using various neurons.

The system **10** also includes a patient interface **50** configured to communicate information to a patient and to receive feedback from the patient. Specifically, the patient interface includes an input device **52** and an output device **54**, which may be collectively called a patient user interface **52**, **54**. The input device **52** may include one or more devices, such as a keyboard, a mouse, a touch screen input, a gesture sensor, and/or a microphone and processor configured for voice recognition. The output device **54** may take one or more different forms including, for example, a computer monitor or display screen on a tablet, smartphone, or a smart watch. The output device **54** may include other hardware and/or software components such as a projector, virtual reality capability, augmented reality capability, etc. The output device **54** may incorporate various different visual, audio, or other presentation technologies. For example, the output device **54** may include a non-visual display, such as an audio signal, which may include spoken language and/or other sounds such as tones, chimes, and/or melodies, which may signal different conditions and/or directions and/or other sensorial or perceptive (e.g., tactile, gustatory, haptic, pressure-sensing-based or electromagnetic (e.g., neurostimulation) communication devices. The output device **54** may comprise one or more different display screens presenting various data and/or interfaces or controls for use by the patient. The output device **54** may include graphics, which may be presented by a web-based interface and/or by a computer program or application (App.).

As shown in FIG. **1**, the patient interface **50** includes a second communication interface **56**, which may also be called a remote communication interface configured to communicate with the server **30** and/or the clinician interface **20** via a second network **58**. In some embodiments, the second network **58** may include a local area network (LAN), such as an Ethernet network. In some embodiments, the second network **58** may include the Internet, and communications between the patient interface **50** and the server **30** and/or the clinician interface **20** may be secured via encryption, such as, for example, by using a virtual private network (VPN). In some embodiments, the second network **58** may include wired and/or wireless network connections such as Wi-Fi, Bluetooth, ZigBee, Near-Field Communications (NFC), cellular data network, etc. In some embodiments, the second network **58** may be the same as and/or operationally coupled to the first network **34**.

The patient interface **50** includes a second processor **60** and a second machine-readable storage memory **62** holding second instructions **64** for execution by the second processor **60** for performing various actions of patient interface **50**. The second machine-readable storage memory **62** also includes a local data store **66** configured to hold data, such as data pertaining to a treatment plan and/or patient data, such as data representing a patient's performance within a treatment plan. The patient interface **50** also includes a local communication interface **68** configured to communicate with various devices for use by the patient in the vicinity of the patient interface **50**. The local communication interface **68** may include wired and/or wireless communications. In some embodiments, the local communication interface **68** may include a local wireless network such as Wi-Fi, Bluetooth, ZigBee, Near-Field Communications (NFC), cellular data network, etc.

The system **10** also includes a treatment apparatus **70** configured to be manipulated by the patient and/or to manipulate a body part of the patient for performing activities according to the treatment plan. In some embodiments, the treatment apparatus **70** may take the form of an exercise and rehabilitation apparatus configured to perform and/or to aid in the performance of a rehabilitation regimen, which may be an orthopedic rehabilitation regimen, and the treatment includes rehabilitation of a body part of the patient, such as a joint or a bone or a muscle group. The treatment apparatus **70** may be any suitable medical, rehabilitative, therapeutic, etc. apparatus configured to be controlled distally via another computing device to treat a patient and/or exercise the patient. The treatment apparatus **70** may be an electromechanical machine including one or more weights, an electromechanical bicycle, an electromechanical spin-wheel, a smart-mirror, a treadmill, or the like. The body part may include, for example, a spine, a hand, a foot, a knee, or a shoulder. The body part may include a part of a joint, a bone, or a muscle group, such as one or more vertebrae, a tendon, or a ligament. As shown in FIG. **1**, the treatment apparatus **70** includes a controller **72**, which may include one or more processors, computer memory, and/or other components. The treatment apparatus **70** also includes a fourth communication interface **74** configured to communicate with the patient interface **50** via the local communication interface **68**. The treatment apparatus **70** also includes one or more internal sensors **76** and an actuator **78**, such as a motor. The actuator **78** may be used, for example, for moving the patient's body part and/or for resisting forces by the patient. The internal sensor **76**, or an external sensor, may also be referred to as, and interchangeable with, an apparatus sensor.

The internal sensors **76** may measure one or more operating characteristics of the treatment apparatus **70** such as, for example, a force, a position, a speed, and/or a velocity. In some embodiments, the internal sensors **76** may include a position sensor configured to measure at least one of a linear motion or an angular motion of a body part of the patient, and/or a position of the internal sensor **76**. For example, an internal sensor **76** in the form of a position sensor may measure a distance that the patient is able to move a part of the treatment apparatus **70**, where such distance may correspond to a range of motion that the patient's body part is able to achieve. In some embodiments, the internal sensors **76** may include a force sensor configured to measure a force applied by the patient. For example, an internal sensor **76** in the form of a force sensor may measure a force or weight the patient is able to apply, using a particular body part, to the treatment apparatus **70**.

The system **10** shown in FIG. **1** also includes an ambulation, or user, sensor **82**, which communicates with the server **30** via the local communication interface **68** of the patient interface **50**. The ambulation sensor **82** may track and store a number of steps taken by the patient. In some embodiments, the ambulation sensor **82** may take the form of a wristband, wristwatch, or smart watch. In some embodiments, the ambulation sensor **82** may be integrated within a phone, such as a smartphone.

The ambulation, or user, sensor **82** may measure one or more operating characteristics of the user such as, for example, a force, a position, a speed, and/or a velocity. In some embodiments, the ambulation sensor **82** may include a plurality of ambulation sensors **82**. In some embodiments, the ambulation sensor **82**, or ambulation sensors, may be configured to, or communicate with the local communication interface to, measure at least one of a linear motion or an angular motion of a body part of the patient, and/or a position of the ambulation sensor **82**, or ambulation sensors. For example, the ambulation sensors **82** may communicate with the local communication interface cooperating with the server to track a location of at least one ambulation sensor **82**, and in turn, a location of the user.

The system **10** shown in FIG. **1** also includes a goniometer **84**, which communicates with the server **30** via the local communication interface **68** of the patient interface **50**. The goniometer **84** measures an angle of the patient's body part. For example, the goniometer **84** may measure the angle of flex of a patient's knee or elbow or shoulder.

The goniometer **84**, or any treatment apparatus, may include one or more treatment sensors (not shown in the FIGS.), configured to measure one or more operating characteristics of the user, such as, for example, a force, a position, a speed, and/or a velocity, of the goniometer **84**. In some embodiments, the treatment sensor may include a plurality of treatment sensors. In some embodiments, the treatment sensor may be configured to, or communicate with the local communication interface to, measure at least one of a linear motion, an angular motion of a body part of the patient, and/or a position of the treatment sensor. For example, the treatment sensor may communicate with the local communication interface cooperating with the server to track a location of the plurality of treatment sensors, and in turn a location of the goniometer **84**.

The system **10** shown in FIG. **1** also includes a pressure sensor **86**, which communicates with the server **30** via the local communication interface **68** of the patient interface **50**. The pressure sensor **86** measures an amount of pressure or weight applied by a body part of the patient. For example, pressure sensor **86** may measure an amount of force applied by a patient's foot when pedaling a stationary bike.

The system **10** shown in FIG. **1** also includes a supervisory interface **90** which may be similar or identical to the clinician interface **20**. In some embodiments, the supervisory interface **90** may have enhanced functionality beyond what is provided on the clinician interface **20**. The supervisory interface **90** may be configured for use by a person having responsibility for the treatment plan, such as an orthopedic surgeon.

The system **10** shown in FIG. **1** also includes a reporting interface **92** which may be similar or identical to the clinician interface **20**. In some embodiments, the reporting interface **92** may have less functionality from what is provided on the clinician interface **20**. For example, the reporting interface **92** may not have the ability to modify a treatment plan. Such a reporting interface **92** may be used, for example, by a biller to determine the use of the system **10** for billing purposes. In another example, the reporting interface **92** may not have the ability to display patient identifiable information, presenting only pseudonymized data and/or anonymized data for certain data fields concerning a data subject and/or for certain data fields concerning a quasi-identifier of the data subject. Such a reporting interface **92** may be used, for example, by a researcher to determine various effects of a treatment plan on different patients.

The system **10** includes an assistant interface **94** for an assistant, such as a doctor, a nurse, a physical therapist, or a technician, to remotely communicate with the patient interface **50** and/or the treatment apparatus **70**. Such remote communications may enable the assistant to provide assistance or guidance to a patient using the system **10**. More specifically, the assistant interface **94** is configured to communicate a telemedicine signal **96**, **97**, **98***a*, **98***b*, **99***a*, **99***b* with the patient interface **50** via a network connection such as, for example, via the first network **34** and/or the second network **58**. The telemedicine signal **96**, **97**, **98***a*, **98***b*, **99***a*, **99***b* comprises one of an audio signal **96**, an audiovisual signal **97**, an interface control signal **98***a* for controlling a function of the patient interface **50**, an interface monitor signal **98***b* for monitoring a status of the patient interface **50**, an apparatus control signal **99***a* for changing an operating parameter of the treatment apparatus **70**, and/or an apparatus monitor signal **99***b* for monitoring a status of the treatment apparatus **70**. In some embodiments, each of the control signals **98***a*, **99***a* may be unidirectional, conveying commands from the assistant interface **94** to the patient interface **50**. In some embodiments, in response to successfully receiving a control signal **98***a*, **99***a* and/or to communicate successful and/or unsuccessful implementation of the requested control action, an acknowledgement message may be sent from the patient interface **50** to the assistant interface **94**. In some embodiments, each of the monitor signals **98***b*, **99***b* may be unidirectional, status-information commands from the patient interface **50** to the assistant interface **94**. In some embodiments, an acknowledgement message may be sent from the assistant interface **94** to the patient interface **50** in response to successfully receiving one of the monitor signals **98***b*, **99***b*.

In some embodiments, the patient interface **50** may be configured as a pass-through for the apparatus control signals **99***a* and the apparatus monitor signals **99***b* between the treatment apparatus **70** and one or more other devices, such as the assistant interface **94** and/or the server **30**. For example, the patient interface **50** may be configured to transmit an apparatus control signal **99***a* in response to an apparatus control signal **99***a* within the telemedicine signal **96**, **97**, **98***a*, **98***b*, **99***a*, **99***b* from the assistant interface **94**.

In some embodiments, the assistant interface **94** may be presented on a shared physical device as the clinician interface **20**. For example, the clinician interface **20** may include one or more screens that implement the assistant interface **94**. Alternatively or additionally, the clinician interface **20** may include additional hardware components, such as a video camera, a speaker, and/or a microphone, to implement aspects of the assistant interface **94**.

In some embodiments, one or more portions of the telemedicine signal **96**, **97**, **98***a*, **98***b*, **99***a*, **99***b* may be generated from a prerecorded source (e.g., an audio recording, a video recording, or an animation) for presentation by the output device **54** of the patient interface **50**. For example, a tutorial video may be streamed from the server **30** and presented upon the patient interface **50**. Content from the prerecorded source may be requested by the patient via the patient interface **50**. Alternatively, via a control on the assistant interface **94**, the assistant may cause content from the prerecorded source to be played on the patient interface **50**.

The assistant interface **94** includes an assistant input device **22** and an assistant display **24**, which may be collectively called an assistant user interface **22**, **24**. The assistant input device **22** may include one or more of a telephone, a keyboard, a mouse, a trackpad, or a touch screen, for example. Alternatively or additionally, the assistant input device **22** may include one or more microphones. In some embodiments, the one or more microphones may take the form of a telephone handset, headset, or wide-area microphone or microphones configured for the assistant to speak to a patient via the patient interface **50**. In some embodiments, assistant input device **22** may be configured to provide voice-based functionalities, with hardware and/or software configured to interpret spoken instructions by the assistant by using the one or more microphones. The assistant input device **22** may include functionality provided by or similar to existing voice-based assistants such as Siri by Apple, Alexa by Amazon, Google Assistant, or Bixby by Samsung. The assistant input device **22** may include other hardware and/or software components. The assistant input device **22** may include one or more general purpose devices and/or special-purpose devices.

The assistant display **24** may take one or more different forms including, for example, a computer monitor or display screen on a tablet, a smartphone, or a smart watch. The assistant display **24** may include other hardware and/or software components such as projectors, virtual reality capabilities, or augmented reality capabilities, etc. The assistant display **24** may incorporate various different visual, audio, or other presentation technologies. For example, the assistant display **24** may include a non-visual display, such as an audio signal, which may include spoken language and/or other sounds such as tones, chimes, melodies, and/or compositions, which may signal different conditions and/or directions. The assistant display **24** may comprise one or more different display screens presenting various data and/or interfaces or controls for use by the assistant. The assistant display **24** may include graphics, which may be presented by a web-based interface and/or by a computer program or application (App.).

In some embodiments, the system **10** may provide computer translation of language from the assistant interface **94** to the patient interface **50** and/or vice-versa. The computer translation of language may include computer translation of spoken language and/or computer translation of text. Additionally or alternatively, the system **10** may provide voice recognition and/or spoken pronunciation of text. For example, the system **10** may convert spoken words to printed text and/or the system **10** may audibly speak language from printed text. The system **10** may be configured to recognize spoken words by any or all of the patient, the clinician, and/or the assistant. In some embodiments, the system **10** may be configured to recognize and react to spoken requests or commands by the patient. For example, the system **10** may automatically initiate a telemedicine session in response to a verbal command by the patient (which may be given in any one of several different languages).

In some embodiments, the server **30** may generate aspects of the assistant display **24** for presentation by the assistant interface **94**. For example, the server **30** may include a web server configured to generate the display screens for presentation upon the assistant display **24**. For example, the artificial intelligence engine **11** may generate recommended treatment plans and/or excluded treatment plans for patients and generate the display screens including those recommended treatment plans and/or external treatment plans for presentation on the assistant display **24** of the assistant interface **94**. In some embodiments, the assistant display **24** may be configured to present a virtualized desktop hosted by the server **30**. In some embodiments, the server **30** may be configured to communicate with the assistant interface **94** via the first network **34**. In some embodiments, the first network **34** may include a local area network (LAN), such as an Ethernet network. In some embodiments, the first network **34** may include the Internet, and communications between the server **30** and the assistant interface **94** may be secured via privacy enhancing technologies, such as, for example, by using encryption over a virtual private network (VPN). Alternatively or additionally, the server **30** may be configured to communicate with the assistant interface **94** via one or more networks independent of the first network **34** and/or other communication means, such as a direct wired or wireless communication channel. In some embodiments, the patient interface **50** and the treatment apparatus **70** may each operate from a patient location geographically separate from a location of the assistant interface **94**. For example, the patient interface **50** and the treatment apparatus **70** may be used as part of an in-home rehabilitation system, which may be aided remotely by using the assistant interface **94** at a centralized location, such as a clinic or a call center.

In some embodiments, the assistant interface **94** may be one of several different terminals (e.g., computing devices) that may be grouped together, for example, in one or more call centers or at one or more clinicians' offices. In some embodiments, a plurality of assistant interfaces **94** may be distributed geographically. In some embodiments, a person may work as an assistant remotely from any conventional office infrastructure. Such remote work may be performed, for example, where the assistant interface **94** takes the form of a computer and/or telephone. This remote work functionality may allow for work-from-home arrangements that may include part time and/or flexible work hours for an assistant.

FIGS. **2-3** show an embodiment of a treatment apparatus **70**. More specifically, FIG. **2** shows a treatment apparatus **70** in the form of a stationary cycling machine **100**, which may be called a stationary bike, for short. The stationary cycling machine **100** includes a set of pedals **102** each attached to a pedal arm **104** for rotation about an axle **106**. In some embodiments, and as shown in FIG. **2**, the pedals **102** are movable on the pedal arms **104** in order to adjust a range of motion used by the patient in pedaling. For example, the pedals being located inwardly toward the axle **106** corresponds to a smaller range of motion than when the pedals are located outwardly away from the axle **106**. A pressure sensor **86** is attached to or embedded within one of the pedals **102** for measuring an amount of force applied by the patient on the pedal **102**. The pressure sensor **86** may communicate wirelessly to the treatment apparatus **70** and/or to the patient interface **50**.

FIG. **4** shows a person (a patient) using the treatment apparatus of FIG. **2**, and showing sensors and various data parameters connected to a patient interface **50**. The example patient interface **50** is a tablet computer or smartphone, or a phablet, such as an iPad, an iPhone, an Android device, or a Surface tablet, which is held manually by the patient. In some other embodiments, the patient interface **50** may be embedded within or attached to the treatment apparatus **70**. FIG. **4** shows the patient wearing the ambulation sensor **82** on his wrist, with a note showing "STEPS TODAY 1355", indicating that the ambulation sensor **82** has recorded and transmitted that step count to the patient interface **50**. FIG. **4** also shows the patient wearing the goniometer **84** on his right knee, with a note showing "KNEE ANGLE 72°", indicating that the goniometer **84** is measuring and transmitting that knee angle to the patient interface **50**. FIG. **4** also shows a right side of one of the pedals **102** with a pressure sensor **86** showing "FORCE 12.5 lbs.," indicating that the right pedal pressure sensor **86** is measuring and transmitting that force measurement to the patient interface **50**. FIG. **4** also shows a left side of one of the pedals **102** with a pressure sensor **86** showing "FORCE 27 lbs.", indicating that the left pedal pressure sensor **86** is measuring and transmitting that force measurement to the patient interface **50**. FIG. **4** also shows other patient data, such as an indicator of "SESSION TIME 0:04:13", indicating that the patient has been using the treatment apparatus **70** for 4 minutes and 13 seconds. This session time may be determined by the patient interface **50** based on information received from the treatment apparatus **70**. FIG. **4** also shows an indicator showing "PAIN LEVEL 3". Such a pain level may be obtained from the patent in response to a solicitation, such as a question, presented upon the patient interface **50**.

FIG. **5** is an example embodiment of an overview display **120** of the assistant interface **94**. Specifically, the overview display **120** presents several different controls and interfaces for the assistant to remotely assist a patient with using the patient interface **50** and/or the treatment apparatus **70**. This remote assistance functionality may also be called telemedicine or telehealth.

Specifically, the overview display **120** includes a patient profile display **130** presenting biographical information regarding a patient using the treatment apparatus **70**. The patient profile display **130** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**, although the patient profile display **130** may take other forms, such as a separate screen or a popup window. In some embodiments, the patient profile display **130** may include a limited subset of the patient's biographical information. More specifically, the data presented upon the patient profile display **130** may depend upon the assistant's need for that information. For example, a healthcare professional that is assisting the patient with a medical issue may be provided with medical history information regarding the patient, whereas a technician troubleshooting an issue with the treatment apparatus **70** may be provided with a much more limited set of information regarding the patient. The technician, for example, may be given only the patient's name. The patient profile display **130** may include pseudonymized data and/or anonymized data or use any privacy enhancing technology to prevent confidential patient data from being communicated in a way that could violate patient confidentiality requirements. Such privacy enhancing technologies may enable compliance with laws, regulations, or other rules of governance such as, but not limited to, the Health Insurance Portability and Accountability Act (HIPAA), or the General Data Protection Regulation (GDPR), wherein the patient may be deemed a "data subject".

In some embodiments, the patient profile display **130** may present information regarding the treatment plan for the patient to follow in using the treatment apparatus **70**. Such treatment plan information may be limited to an assistant who is a healthcare professional, such as a doctor or physical therapist. For example, a healthcare professional assisting the patient with an issue regarding the treatment regimen may be provided with treatment plan information, whereas a technician troubleshooting an issue with the treatment apparatus **70** may not be provided with any information regarding the patient's treatment plan.

In some embodiments, one or more recommended treatment plans and/or excluded treatment plans may be presented in the patient profile display **130** to the assistant. The one or more recommended treatment plans and/or excluded treatment plans may be generated by the artificial intelligence engine **11** of the server **30** and received from the server **30** in real-time during, inter alia, a telemedicine or telehealth session. An example of presenting the one or more recommended treatment plans and/or ruled-out treatment plans is described below with reference to FIG. **7**.

The example overview display **120** shown in FIG. **5** also includes a patient status display **134** presenting status information regarding a patient using the treatment apparatus. The patient status display **134** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**, although the patient status display **134** may take other forms, such as a separate screen or a popup window. The patient status display **134** includes sensor data **136** from one or more of the external sensors **82**, **84**, **86**, and/or from one or more internal sensors **76** of the treatment apparatus **70**. In some embodiments, the patient status display **134** may present other data **138** regarding the patient, such as last reported pain level, or progress within a treatment plan.

User access controls may be used to limit access, including what data is available to be viewed and/or modified, on any or all of the user interfaces **20**, **50**, **90**, **92**, **94** of the system **10**. In some embodiments, user access controls may be employed to control what information is available to any given person using the system **10**. For example, data presented on the assistant interface **94** may be controlled by user access controls, with permissions set depending on the assistant/user's need for and/or qualifications to view that information.

The example overview display **120** shown in FIG. **5** also includes a help data display **140** presenting information for the assistant to use in assisting the patient. The help data display **140** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The help data display **140** may take other forms, such as a separate screen or a popup window. The help data display **140** may include, for example, presenting answers to frequently asked questions regarding use of the patient interface **50** and/or the treatment apparatus **70**. The help data display **140** may also include research data or best practices. In some embodiments, the help data display **140** may present scripts for answers or explanations in response to patient questions. In some embodiments, the help data display **140** may present flow charts or walk-throughs for the assistant to use in determining a root cause and/or solution to a patient's problem. In some embodiments, the assistant interface **94** may present two or more help data displays **140**, which may be the same or different, for simultaneous presentation of help data for use by the assistant. for example, a first help data display may be used to present a troubleshooting flowchart to determine the source of a patient's problem, and a second help data display may present script information for the assistant to read to the patient, such information to preferably include directions for the patient to perform some action, which may help to narrow down or solve the problem. In some embodiments, based upon inputs to the troubleshooting flowchart in the first help data display, the second help data display may automatically populate with script information.

The example overview display **120** shown in FIG. **5** also includes a patient interface control **150** presenting information regarding the patient interface **50**, and/or to modify one or more settings of the patient interface **50**. The patient interface control **150** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The patient interface control **150** may take other forms, such as a separate screen or a popup window. The patient interface control **150** may present information communicated to the assistant interface **94** via one or more of the interface monitor signals **98*b***. As shown in FIG. **5**, the patient interface control **150** includes a display feed **152** of the display presented by the patient interface **50**. In some embodiments, the display feed **152** may include a live copy of the display screen currently being presented to the patient by the patient interface **50**. In other words, the display feed

152 may present an image of what is presented on a display screen of the patient interface **50**. In some embodiments, the display feed **152** may include abbreviated information regarding the display screen currently being presented by the patient interface **50**, such as a screen name or a screen number. The patient interface control **150** may include a patient interface setting control **154** for the assistant to adjust or to control one or more settings or aspects of the patient interface **50**. In some embodiments, the patient interface setting control **154** may cause the assistant interface **94** to generate and/or to transmit an interface control signal **98** for controlling a function or a setting of the patient interface **50**.

In some embodiments, the patient interface setting control **154** may include collaborative browsing or co-browsing capability for the assistant to remotely view and/or control the patient interface **50**. For example, the patient interface setting control **154** may enable the assistant to remotely enter text to one or more text entry fields on the patient interface **50** and/or to remotely control a cursor on the patient interface **50** using a mouse or touchscreen of the assistant interface **94**.

In some embodiments, using the patient interface **50**, the patient interface setting control **154** may allow the assistant to change a setting that cannot be changed by the patient. For example, the patient interface **50** may be precluded from accessing a language setting to prevent a patient from inadvertently switching, on the patient interface **50**, the language used for the displays, whereas the patient interface setting control **154** may enable the assistant to change the language setting of the patient interface **50**. In another example, the patient interface **50** may not be able to change a font size setting to a smaller size in order to prevent a patient from inadvertently switching the font size used for the displays on the patient interface **50** such that the display would become illegible to the patient, whereas the patient interface setting control **154** may provide for the assistant to change the font size setting of the patient interface **50**.

The example overview display **120** shown in FIG. **5** also includes an interface communications display **156** showing the status of communications between the patient interface **50** and one or more other devices **70**, **82**, **84**, such as the treatment apparatus **70**, the ambulation sensor **82**, and/or the goniometer **84**. The interface communications display **156** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The interface communications display **156** may take other forms, such as a separate screen or a popup window. The interface communications display **156** may include controls for the assistant to remotely modify communications with one or more of the other devices **70**, **82**, **84**. For example, the assistant may remotely command the patient interface **50** to reset communications with one of the other devices **70**, **82**, **84**, or to establish communications with a new one of the other devices **70**, **82**, **84**. This functionality may be used, for example, where the patient has a problem with one of the other devices **70**, **82**, **84**, or where the patient receives a new or a replacement one of the other devices **70**, **82**, **84**.

The example overview display **120** shown in FIG. **5** also includes an apparatus control **160** for the assistant to view and/or to control information regarding the treatment apparatus **70**. The apparatus control **160** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The apparatus control **160** may take other forms, such as a separate screen or a popup window. The apparatus control **160** may include an apparatus status display **162** with information regarding the current status of the apparatus. The apparatus status display **162** may present information communicated to the assistant interface **94** via one or more of the apparatus monitor signals **99***b*. The apparatus status display **162** may indicate whether the treatment apparatus **70** is currently communicating with the patient interface **50**. The apparatus status display **162** may present other current and/or historical information regarding the status of the treatment apparatus **70**.

The apparatus control **160** may include an apparatus setting control **164** for the assistant to adjust or control one or more aspects of the treatment apparatus **70**. The apparatus setting control **164** may cause the assistant interface **94** to generate and/or to transmit an apparatus control signal **99** for changing an operating parameter of the treatment apparatus **70**, (e.g., a pedal radius setting, a resistance setting, a target RPM, etc.). The apparatus setting control **164** may include a mode button **166** and a position control **168**, which may be used in conjunction for the assistant to place an actuator **78** of the treatment apparatus **70** in a manual mode, after which a setting, such as a position or a speed of the actuator **78**, can be changed using the position control **168**. The mode button **166** may provide for a setting, such as a position, to be toggled between automatic and manual modes. In some embodiments, one or more settings may be adjustable at any time, and without having an associated auto/manual mode. In some embodiments, the assistant may change an operating parameter of the treatment apparatus **70**, such as a pedal radius setting, while the patient is actively using the treatment apparatus **70**. Such "on the fly" adjustment may or may not be available to the patient using the patient interface **50**. In some embodiments, the apparatus setting control **164** may allow the assistant to change a setting that cannot be changed by the patient using the patient interface **50**. For example, the patient interface **50** may be precluded from changing a preconfigured setting, such as a height or a tilt setting of the treatment apparatus **70**, whereas the apparatus setting control **164** may provide for the assistant to change the height or tilt setting of the treatment apparatus **70**.

The example overview display **120** shown in FIG. **5** also includes a patient communications control **170** for controlling an audio or an audiovisual communications session with the patient interface **50**. The communications session with the patient interface **50** may comprise a live feed from the assistant interface **94** for presentation by the output device of the patient interface **50**. The live feed may take the form of an audio feed and/or a video feed. In some embodiments, the patient interface **50** may be configured to provide two-way audio or audiovisual communications with a person using the assistant interface **94**. Specifically, the communications session with the patient interface **50** may include bidirectional (two-way) video or audiovisual feeds, with each of the patient interface **50** and the assistant interface **94** presenting video of the other one. In some embodiments, the patient interface **50** may present video from the assistant interface **94**, while the assistant interface **94** presents only audio or the assistant interface **94** presents no live audio or visual signal from the patient interface **50**. In some embodiments, the assistant interface **94** may present video from the patient interface **50**, while the patient interface **50** presents only audio or the patient interface **50** presents no live audio or visual signal from the assistant interface **94**.

In some embodiments, the audio or an audiovisual communications session with the patient interface **50** may take place, at least in part, while the patient is performing the rehabilitation regimen upon the body part. The patient communications control **170** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The patient communications control **170** may take other forms, such as a separate screen or a popup window. The audio and/or audiovisual communications may be processed and/or directed by the assistant interface **94** and/or by another device or devices, such as a telephone system, or a videoconferencing system used by the assistant while the assistant uses the assistant interface **94**. Alternatively or additionally, the audio and/or audiovisual communications may include communications with a third party. For example, the system **10** may enable the assistant to initiate a 3-way conversation regarding use of a particular piece of hardware or software, with the patient and a subject matter expert, such as a healthcare professional or a specialist. The example patient communications control **170** shown in FIG. **5** includes call controls **172** for the assistant to use in managing various aspects of the audio or audiovisual communications with the patient. The call controls **172** include a disconnect button **174** for the assistant to end the audio or audiovisual communications session. The call controls **172** also include a mute button **176** to temporarily silence an audio or audiovisual signal from the assistant interface **94**. In some embodiments, the call controls **172** may include other features, such as a hold button (not shown). The call controls **172** also include one or more record/playback controls **178**, such as record, play, and pause buttons to control, with the patient interface **50**, recording and/or playback of audio and/or video from the teleconference session. The call controls **172** also include a video feed display **180** for presenting still and/or video images from the patient interface **50**, and a self-video display **182** showing the current image of the assistant using the assistant interface. The self-video display **182** may be presented as a picture-in-picture format, within a section of the video feed display **180**, as shown in FIG. **5**. Alternatively or additionally, the self-video display **182** may be presented separately and/or independently from the video feed display **180**.

The example overview display **120** shown in FIG. **5** also includes a third party communications control **190** for use in conducting audio and/or audiovisual communications with a third party. The third party communications control **190** may take the form of a portion or region of the overview display **120**, as shown in FIG. **5**. The third party communications control **190** may take other forms, such as a display on a separate screen or a popup window. The third party communications control **190** may include one or more controls, such as a contact list and/or buttons or controls to contact a third party regarding use of a particular piece of hardware or software, e.g., a subject matter expert, such as a healthcare professional or a specialist. The third party communications control **190** may include conference calling capability for the third party to simultaneously communicate with both the assistant via the assistant interface **94**, and with the patient via the patient interface **50**. For example, the system **10** may provide for the assistant to initiate a 3-way conversation with the patient and the third party.

FIG. **6** shows an example block diagram of training a machine learning model **13** to output, based on data **600** pertaining to the patient, a treatment plan **602** for the patient according to the present disclosure. Data pertaining to other patients may be received by the server **30**. The other patients may have used various treatment apparatuses to perform treatment plans. The data may include characteristics of the other patients, the details of the treatment plans performed by the other patients, and/or the results of performing the treatment plans (e.g., a percent of recovery of a portion of the patients' bodies, an amount of recovery of a portion of the patients' bodies, an amount of increase or decrease in muscle strength of a portion of patients' bodies, an amount of increase or decrease in range of motion of a portion of patients' bodies, etc.).

As depicted, the data has been assigned to different cohorts. Cohort A includes data for patients having similar first characteristics, first treatment plans, and first results. Cohort B includes data for patients having similar second characteristics, second treatment plans, and second results. For example, cohort A may include first characteristics of patients in their twenties without any medical conditions who underwent surgery for a broken limb; their treatment plans may include a certain treatment protocol (e.g., use the treatment apparatus **70** for 30 minutes 5 times a week for 3 weeks, wherein values for the properties, configurations, and/or settings of the treatment apparatus **70** are set to X (where X is a numerical value) for the first two weeks and to Y (where Y is a numerical value) for the last week).

Cohort A and cohort B may be included in a training dataset used to train the machine learning model **13**. The machine learning model **13** may be trained to match a pattern between characteristics for each cohort and output the treatment plan that provides the result. Accordingly, when the data **600** for a new patient is input into the trained machine learning model **13**, the trained machine learning model **13** may match the characteristics included in the data **600** with characteristics in either cohort A or cohort B and output the appropriate treatment plan **602**. In some embodiments, the machine learning model **13** may be trained to output one or more excluded treatment plans that should not be performed by the new patient.

FIG. **7** shows an embodiment of an overview display **120** of the assistant interface **94** presenting recommended treatment plans and excluded treatment plans in real-time during a telemedicine session according to the present disclosure. As depicted, the overview display **120** just includes sections for the patient profile **130** and the video feed display **180**, including the self-video display **182**. Any suitable configuration of controls and interfaces of the overview display **120** described with reference to FIG. **5** may be presented in addition to or instead of the patient profile **130**, the video feed display **180**, and the self-video display **182**.

The assistant (e.g., healthcare professional) using the assistant interface **94** (e.g., computing device) during the telemedicine session may be presented in the self-video **182** in a portion of the overview display **120** (e.g., user interface presented on a display screen **24** of the assistant interface **94**) that also presents a video from the patient in the video feed display **180**. Further, the video feed display **180** may also include a graphical user interface (GUI) object **700** (e.g., a button) that enables the healthcare professional to share on the patient interface **50**, in real-time or near real-time during the telemedicine session, the recommended treatment plans and/or the excluded treatment plan with the patient. The healthcare professional may select the GUI object **700** to share the recommended treatment plans and/or the excluded treatment plans. As depicted, another portion of the overview display **120** includes the patient profile display **130**.

The patient profile display **130** is presenting two example recommended treatment plans **600** and one example excluded treatment plan **602**. As described herein, the treatment plans may be recommended in view of characteristics of the patient being treated. To generate the recommended treatment plans **600** the patient should follow to achieve a desired result, a pattern between the characteristics of the patient being treated and a cohort of other people who have used the treatment apparatus **70** to perform a treatment plan may be matched by one or more machine learning models **13** of the artificial intelligence engine **11**. Each of the recommended treatment plans may be generated based on different desired results.

For example, as depicted, the patient profile display **130** presents "The characteristics of the patient match characteristics of users in Cohort A. The following treatment plans are recommended for the patient based on his characteristics and desired results." Then, the patient profile display **130** presents recommended treatment plans from cohort A, and each treatment plan provides different results.

As depicted, treatment plan "A" indicates "Patient X should use treatment apparatus for 30 minutes a day for 4 days to achieve an increased range of motion of Y %; Patient X has Type 2 Diabetes; and Patient X should be prescribed medication Z for pain management during the treatment plan (medication Z is approved for people having Type 2 Diabetes)." Accordingly, the treatment plan generated achieves increasing the range of motion of Y %. As may be appreciated, the treatment plan also includes a recommended medication (e.g., medication Z) to prescribe to the patient to manage pain in view of a known medical disease (e.g., Type 2 Diabetes) of the patient. That is, the recommended patient medication not only does not conflict with the medical condition of the patient but thereby improves the probability of a superior patient outcome. This specific example and all such examples elsewhere herein are not intended to limit in any way the generated treatment plan from recommending multiple medications, or from handling the acknowledgement, view, diagnosis and/or treatment of comorbid conditions or diseases.

Recommended treatment plan "B" may specify, based on a different desired result of the treatment plan, a different treatment plan including a different treatment protocol for a treatment apparatus, a different medication regimen, etc.

As depicted, the patient profile display **130** may also present the excluded treatment plans **602**. These types of treatment plans are shown to the assistant using the assistant interface **94** to alert the assistant not to recommend certain portions of a treatment plan to the patient. For example, the excluded treatment plan could specify the following: "Patient X should not use treatment apparatus for longer than 30 minutes a day due to a heart condition; Patient X has Type 2 Diabetes; and Patient X should not be prescribed medication M for pain management during the treatment plan (in this scenario, medication M can cause complications for people having Type 2 Diabetes). Specifically, the excluded treatment plan points out a limitation of a treatment protocol where, due to a heart condition, Patient X should not exercise for more than 30 minutes a day. The ruled-out treatment plan also points out that Patient X should not be prescribed medication M because it conflicts with the medical condition Type 2 Diabetes.

The assistant may select the treatment plan for the patient on the overview display **120**. For example, the assistant may use an input peripheral (e.g., mouse, touchscreen, microphone, keyboard, etc.) to select from the treatment plans **600** for the patient. In some embodiments, during the telemedicine session, the assistant may discuss the pros and cons of the recommended treatment plans **600** with the patient.

In any event, the assistant may select the treatment plan for the patient to follow to achieve the desired result. The selected treatment plan may be transmitted to the patient interface **50** for presentation. The patient may view the selected treatment plan on the patient interface **50**. In some embodiments, the assistant and the patient may discuss during the telemedicine session the details (e.g., treatment protocol using treatment apparatus **70**, diet regimen, medication regimen, etc.) in real-time or in near real-time. In some embodiments, the server **30** may control, based on the selected treatment plan and during the telemedicine session, the treatment apparatus **70** as the user uses the treatment apparatus **70**.

FIG. **8** shows an embodiment of the overview display **120** of the assistant interface **94** presenting, in real-time during a telemedicine session, recommended treatment plans that have changed as a result of patient data changing according to the present disclosure. As may be appreciated, the treatment apparatus **70** and/or any computing device (e.g., patient interface **50**) may transmit data while the patient uses the treatment apparatus **70** to perform a treatment plan. The data may include updated characteristics of the patient. For example, the updated characteristics may include new performance information and/or measurement information. The performance information may include a speed of a portion of the treatment apparatus **70**, a range of motion achieved by the patient, a force exerted on a portion of the treatment apparatus **70**, a heartrate of the patient, a blood pressure of the patient, a respiratory rate of the patient, and so forth.

In one embodiment, the data received at the server **30** may be input into the trained machine learning model **13**, which may determine that the characteristics indicate the patient is on track for the current treatment plan. Determining the patient is on track for the current treatment plan may cause the trained machine learning model **13** to adjust a parameter of the treatment apparatus **70**. The adjustment may be based on a next step of the treatment plan to further improve the performance of the patient.

In one embodiment, the data received at the server **30** may be input into the trained machine learning model **13**, which may determine that the characteristics indicate the patient is not on track (e.g., behind schedule, not able to maintain a speed, not able to achieve a certain range of motion, is in too much pain, etc.) for the current treatment plan or is ahead of schedule (e.g., exceeding a certain speed, exercising longer than specified with no pain, exerting more than a specified force, etc.) for the current treatment plan. The trained machine learning model **13** may determine that the characteristics of the patient no longer match the characteristics of the patients in the cohort to which the patient is assigned. Accordingly, the trained machine learning model **13** may reassign the patient to another cohort that includes qualifying characteristics the patient's characteristics. As such, the trained machine learning model **13** may select a new treatment plan from the new cohort and control, based on the new treatment plan, the treatment apparatus **70**.

In some embodiments, prior to controlling the treatment apparatus **70**, the server **30** may provide the new treatment plan **800** to the assistant interface **94** for presentation in the patient profile **130**. As depicted, the patient profile **130** indicates "The characteristics of the patient have changed and now match characteristics of users in Cohort B. The following treatment plan is recommended for the patient based on his characteristics and desired results." Then, the patient profile **130** presents the new treatment plan **800** ("Patient X should use treatment apparatus for 10 minutes a day for 3 days to achieve an increased range of motion of L %". The assistant (healthcare professional) may select the new treatment plan **800**, and the server **30** may receive the selection. The server **30** may control the treatment apparatus **70** based on the new treatment plan **800**. In some embodiments, the new treatment plan **800** may be transmitted to the patient interface **50** such that the patient may view the details of the new treatment plan **800**.

FIG. 9 shows an example embodiment of a method **900** for selecting, based on assigning a patient to a cohort, a treatment plan for the patient and controlling, based on the treatment plan, a treatment apparatus according to the present disclosure. The method **900** is performed by processing logic that may include hardware (circuitry, dedicated logic, etc.), software (such as is run on a general-purpose computer system or a dedicated machine), or a combination of both. The method **900** and/or each of its individual functions, routines, subroutines, or operations may be performed by one or more processors of a computing device (e.g., any component of FIG. **1**, such as server **30** executing the artificial intelligence engine **11**). In certain implementations, the method **900** may be performed by a single processing thread. Alternatively, the method **800** may be performed by two or more processing threads, each thread implementing one or more individual functions, routines, subroutines, or operations of the methods.

For simplicity of explanation, the method **900** is depicted and described as a series of operations. However, operations in accordance with this disclosure can occur in various orders and/or concurrently, and/or with other operations not presented and described herein. For example, the operations depicted in the method **900** may occur in combination with any other operation of any other method disclosed herein. Furthermore, not all illustrated operations may be required to implement the method **900** in accordance with the disclosed subject matter. In addition, those skilled in the art will understand and appreciate that the method **900** could alternatively be represented as a series of interrelated states via a state diagram or events.

At **902**, the processing device may receive first data pertaining to a first user that uses a treatment apparatus **70** to perform a treatment plan. The first data may include characteristics of the first user, the treatment plan, and a result of the treatment plan.

At **904**, the processing device may assign, based on the first data, the first user to a first cohort representing people having similarities to at least some of the characteristics of the first user, the treatment plan, and the result of the treatment plan.

At **906**, the processing device may receive second data pertaining to a second user. The second data may include characteristics of the second user. The characteristics of the first user and the second user may include personal information, performance information, measurement information, or some combination thereof. In some embodiments, the personal information may include an age, a weight, a gender, a height, a body mass index, a medical condition, a familial medication history, an injury, or a medical procedure. In some embodiments, the performance information may include an elapsed time of using the treatment apparatus, an amount of force exerted on a portion of the treatment apparatus, a range of motion achieved on the treatment apparatus, a movement speed of a portion of the treatment apparatus, an indication of a set of pain levels using the treatment apparatus, or some combination thereof. In some embodiments, the measurement information may include a vital sign, a respiration rate, a heartrate, a temperature, or some combination thereof.

At **908**, the processing device may determine whether at least some of the characteristics of the second user match with at least some of the characteristics of the first user assigned to the first cohort. In some embodiments, one or more machine learning models may be trained to determine whether at least the characteristics of the second user match the characteristics of the first user assigned to the first cohort.

At **910**, responsive to determining the at least some of the characteristics of the second user match with at least some of the characteristics of the first user, the processing device may assign the second user to the first cohort and select, via a trained machine learning model, the treatment plan for the second user. In some embodiments, the trained machine learning model is trained, using at least the first data, to compare, in real-time or near real-time, the second data of the second user to a set of data stored in a set of cohorts and select the treatment plan that leads to a desired result and that includes characteristics that match the second characteristics of the second user. The set of cohorts may include the first cohort.

The treatment plan may include a treatment protocol that specifies using the treatment apparatus **70** to perform certain exercises for certain lengths of time and a periodicity for performing the exercises. The treatment protocol may also specify parameters of the treatment apparatus **70** for each of the exercises. For example, a two-week treatment protocol for a person having certain characteristics (e.g., respiration, weight, age, injury, current range of motion, heartrate, etc.) may specify the exercises for a first week and a second week. The exercise for the first week may include pedaling a bicycle for a 10-minute time period where the pedals gradually increase or decrease a range of motion every 1 minute throughout the 10-minute time period. The exercise for the second week may include pedaling a bicycle for a 5-minute time period where the pedals aggressively increase or decrease a range of motion every 1 minute throughout the 10-minute time period.

At **912**, the processing device may control, based on the treatment plan, the treatment apparatus **70** while the second user uses the treatment apparatus. In some embodiments, the controlling may be performed by the server **30** distal from the treatment apparatus **70** (e.g., during a telemedicine session). Controlling the treatment apparatus **70** distally may include the server **30** transmitting, based on the treatment plan, a control instruction to change a parameter of the treatment apparatus **70** at a particular time to increase a likelihood of a positive effect of continuing to use the treatment apparatus or to decrease a likelihood of a negative effect of continuing to use the treatment apparatus. For example, the treatment plan may include information (based on historical information of people having certain characteristics and performing exercises in the treatment plan) indicating there may be diminishing returns after a certain amount of time of performing a certain exercise. Accordingly, the server **30**, executing one or more machine learning models **13**, may transmit a control signal to the treatment apparatus **70** to cause the treatment apparatus **70** to change a parameter (e.g., slow down, stop, etc.).

In some embodiments, the treatment apparatus used by the first user and the treatment apparatus used by the second user may be the same, or the treatment apparatus used by the first user and the treatment apparatus used by the second user may be different. For example, if the first user and the second user are members of a family, then they may use the same treatment apparatus. If the first user and the second user live in different residences, then the first user and the second user may use different treatment apparatuses.

In some embodiments, the processing device may continue to receive data while the second user uses the treatment apparatus **70** to perform the treatment plan. The data received may include characteristics of the second user while the second user uses the treatment apparatus **70** to perform the treatment plan. The characteristics may include information pertaining to measurements (e.g., respiration, heartrate, temperature, perspiration) and performance (e.g., range of motion, force exerted on a portion of the treatment apparatus **70**, speed of actuating a portion of the treatment apparatus **70**, etc.). The data may indicate that the second user is improving (e.g., maintaining a desired speed of the treatment plan, range of motion, and/or force) as expected in view of the treatment plan for a person having similar data. Accordingly, the processing device may adjust, via a trained machine learning model **13**, based on the data and the treatment plan, a parameter of the treatment apparatus **70**. For example, the data may indicate the second user is pedaling a portion of the treatment apparatus **70** for 3 minutes at a certain speed. Thus, the machine learning model may adjust, based on the data and the treatment plan, an amount of resistance of the pedals to attempt to cause the second user to achieve a certain result (e.g., strengthen one or more muscles). The certain result may have been achieved by other users with similar data (e.g., characteristics including performance, measurements, etc.) exhibited by the second user at a particular point in a treatment plan.

In some embodiments, the processing device may receive, from the treatment apparatus **70**, data pertaining to second characteristics of the second user while the second user uses the treatment apparatus **70** to perform the treatment plan. The second characteristics may include information pertaining to measurements (e.g., respiration, heartrate, temperature, perspiration) and performance (e.g., range of motion, force exerted on a portion of the treatment apparatus **70**, speed of actuating a portion of the treatment apparatus **70**, etc.) of the second user as the second user uses the treatment apparatus **70** to perform the treatment plan. In some embodiments, the processing device may determine, based on the characteristics, that the second user is improving faster than expected for the treatment plan or is not improving (e.g., unable to maintain a desired speed of the treatment plan, range of motion, and/or force) as expected for the treatment plan.

The processing device may determine that the second characteristics of the second user match characteristics of a third user assigned to a second cohort. The second cohort may include data for people having different characteristics than the cohort to which the second user was initially assigned. Responsive to determining the second characteristics of the second user match the characteristics of the third user, the processing device may assign the second user to the second cohort and select, via the trained machine learning model, a second treatment plan for the second user. Accordingly, the treatment plans for a user using the treatment apparatus **70** may be dynamically adjusted, in real-time while the user is using the treatment apparatus **70**, to best fit the characteristics of the second user and enhance a likelihood the second user achieves a desired result experienced by other people in a particular cohort to which the second user is assigned. The second treatment plan may have been performed by the third user with similar characteristics to the second user, and as a result of performing the second treatment plan, the third user may have achieved a desired result. The processing device may control, based on the second treatment plan, the treatment apparatus **70** while the second user uses the treatment apparatus.

In some embodiments, responsive to determining the characteristics of the second user do not match the characteristics of the first user, the processing device may determine whether at least the characteristics of the second user match characteristics of a third user assigned to a second cohort. Responsive to determining the characteristics of the second user match the characteristics of the third user, the processing device may assign the second user to the second cohort and select, via the trained machine learning model, a second treatment plan for the second user. The second treatment plan may have been performed by the third user with similar characteristics to the second user, and as a result of performing the second treatment plan, the third user may have achieved a desired result. The processing device may control, based on the second treatment plan, the treatment apparatus **70** while the second user uses the treatment apparatus.

FIG. **10** shows an example embodiment of a method **1000** for presenting, during a telemedicine session, the recommended treatment plan to a healthcare professional according to the present disclosure. Method **1000** includes operations performed by processors of a computing device (e.g., any component of FIG. **1**, such as server **30** executing the artificial intelligence engine **11**). In some embodiments, one or more operations of the method **1000** are implemented in computer instructions stored on a memory device and executed by a processing device. The method **1000** may be performed in the same or a similar manner as described above in regard to method **900**. The operations of the method **1000** may be performed in some combination with any of the operations of any of the methods described herein.

In some embodiments, the method **1000** may occur after **910** and prior to **912** in the method **900** depicted in FIG. **9**. That is, the method **1000** may occur prior to the server **30** executing the one or more machine learning models **13** controlling the treatment apparatus **70**.

Regarding the method **1000**, at **1002**, prior to controlling the treatment apparatus **70** while the second user uses the treatment apparatus **70**, the processing device may provide, during a telemedicine or telehealth session, a recommendation pertaining to the treatment plan to a computing device (e.g., assistant interface **94**) of a healthcare professional. The recommendation may be presented on a display screen of the computing device in real-time (e.g., less than 2 seconds) in a portion of the display screen while another portion of the display screen presents video of a user (e.g., patient).

At **1004**, the processing device may receive, from the computing device of the healthcare professional, a selection of the treatment plan. The healthcare professional may use any suitable input peripheral (e.g., mouse, keyboard, microphone, touchpad, etc.) to select the recommended treatment plan. The computing device may transmit the selection to the processing device of the server **30**, which receives the selection. There may any suitable number of treatment plans presented on the display screen. Each of the treatment plans recommended may provide different results and the healthcare professional may consult, during the telemedicine session, with the user to discuss which result the user desires. In some embodiments, the recommended treatment plans may only be presented on the computing device of the healthcare professional and not on the computing device of the user (patient interface **50**). In some embodiments, the healthcare professional may choose an option presented on the assistant interface **94**. The option may cause the treatment plans to be transmitted to the patient interface **50** for presentation. In this way, during the telemedicine session, the healthcare professional and the user may view the treatment plans at the same time in real-time or in near real-time, which may provide for an enhanced user experience for the user using the computing device. After the selection of the treatment plan is received at the server **30**, at **1006**, the processing device may control, based on the selected treatment plan, the treatment apparatus while the second user uses the treatment apparatus **70**.

In some embodiments, the processor, or processing device, **36** may generate an enhanced environment representative of an environment. The enhanced environment may be displayed in the patient interface **50**. The patient interface **50** may be one of an augmented reality device, a virtual reality device, a mixed reality device, and an immersive reality device configured to present the enhanced environment. The enhanced environment may be any of a selected or predetermined environment, e.g., a template living room or rehabilitation center. The enhanced environment may be selected from a menu displayed in the patient interface **50** and displaying one or more option for the enhanced environment.

In some embodiments, the processor **36** may receive, from the apparatus sensors **76**, apparatus data representative of a location of the apparatus in the environment. For example, the apparatus sensors **76** may communicate with the server **30**, and in turn, the processors **36**, the data associated with a location of the apparatus sensors **76**, and in turn, the apparatus **70** in the environment. The processors **36** may also generate, from the apparatus data, an apparatus avatar in the enhanced environment.

In some embodiments, the processor **36** may also receive, from the user sensors **82**, user data representative of a location of the user in the environment. For example, the user sensors **82** may communicate with the server **30**. In turn, the processors **36** may receive, from the server **30**, the data associated with a location of the user sensors **82**, and in turn, the apparatus **70** in the environment. The processors **36** may generate, from the user data, a user avatar in the enhanced environment.

In some embodiments, the processor **36** may also receive, from the treatment sensors (not illustrated), treatment data representative of one or more locations of the treatment sensors in the environment. For example, the user sensors **82** may communicate with the server **30**, and in turn, the processors **36**, the data associated with a location of the user sensors **82**, and in turn, the apparatus **70** in the environment. In some embodiments, the processors **36** may generate, from the treatment data, treatment sensor avatars in the enhanced environment.

In some embodiments, the processor **36** may calculate, based on one or more of the apparatus data and the user data, a treatment location for each treatment sensor, wherein the treatment location is associated with an anatomical structure of a user. The processor **36** may further generate, based on the treatment location and treatment data, instruction data representing an instruction for positioning the treatment sensors at the treatment location. The instruction data may represent instructions capable of altering the location of the treatment sensor to be one of adjacent to, at, and near the treatment location. The instruction data may represent instruction confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location. For example, when the goniometer is located at an ideal location on the user, the instruction data represents instruction confirming the goniometer is in an optimal position on the user for rehabilitation. In another example, when the goniometer is not in an optimal position on the user for rehabilitation, the instruction data represents instruction confirming the goniometer is out of place and needs to be moved. The instruction may represent one or more of arrows, a color-coded indicator, an audible indication and a textual message. The instruction can be any medium suitable for communicating with a user. The instruction may be one or more of a color-coded indication, audible indication, a textual message, and/or other sensorial or perceptive (e.g., tactile, gustatory, haptic, pressure-sensing-based or electromagnetic (e.g., neurostimulation) communication indication.

In some embodiments, the processor **36** may output, to the patient (or user) interface **50** and based on the environment data, an image representative of the enhanced environment. Further, the processors **36** may output, to the patient interface **50** (or any other interface, such as: the assistance interface **94**, reporting interface **92**, supervisory interface **90**, clinician interface **20**), an image representing the user, apparatus and treatment sensor avatars. The avatars can be of any shape or form sufficient to communicate with a user the relative location of object in the enhanced environment. The processor **36** may also generate, based on the treatment location, a treatment location avatar. The processors **36** may output, to the patient interface **50**, an image representing the treatment location avatar. The treatment location avatar may be one of overlaid on and transposed with a portion of the user avatar. For example, the treatment location avatar would display as if on the user avatar and represent a location where the goniometer is to be placed. The processors **36** is may output, to the patient interface **5050**, the treatment location avatar in a frequency, or pattern, configured to cause the avatar to flash and wherein the frequency of flashing is one or more of: variable (e.g. the treatment location avatar blinks); static (e.g., the treatment avatar does not blink but presented as a shaded object or an object outlined by a solid line); and based on the instruction data.

The processor **36** may output, to the patient interface **50**, instructions confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location. The processor **36** may output, to the patient interface **50**, instructions to move the location of the treatment sensor to the treatment location. The instruction can be any one of the instruction discussed above, or in any other form sufficient to communicate with a user.

In some embodiments, the processor **36** may receive, during a telemedicine-enabled appointment between the user and a healthcare professional, medical instruction data representative of instructions from the healthcare professional. The processor **36** may output, to the user interface **50** and based on the medical instruction data, instructions from the healthcare professional. The medical instruction data refers to a recommended treatment location. A medical interface remote from the user and associated with the healthcare professional, and wherein the processing device is further configured to output, to the medical interface, a user response to the medical instruction.

FIG. **11** shows an example computer system **1100** which can perform any one or more of the methods described herein, in accordance with one or more aspects of the present disclosure. In one example, computer system **1100** may include a computing device and correspond to the assistance interface **94**, the reporting interface **92**, the supervisory interface **90**, the clinician interface **20**, the server **30** (including the AI engine **11**), the patient interface **50**, the ambulatory sensor **82**, the goniometer **84**, the treatment apparatus **70**, the pressure sensor **86**, or any suitable component of FIG. **1**. The computer system **1100** may be capable of executing instructions implementing the one or more machine learning models **13** of the artificial intelligence engine **11** of FIG. **1**. The computer system may be connected (e.g., networked) to other computer systems in a LAN, an intranet, an extranet, or the Internet, including via the cloud or a peer-to-peer network. The computer system may operate in the capacity of a server in a client-server network environment. The computer system may be a personal computer (PC), a tablet computer, a wearable (e.g., wristband), a set-top box (STB), a personal Digital Assistant (PDA), a mobile phone, a camera, a video camera, an Internet of Things (IoT) device, or any device capable of executing a set of instructions (sequential or otherwise) that specify actions to be taken by that device. Further, while only a single computer system is illustrated, the term "computer" shall also be taken to include any collection of computers that individually or jointly execute a set (or multiple sets) of instructions to perform any one or more of the methods discussed herein.

The computer system **1100** includes a processing device **1102**, a main memory **1104** (e.g., read-only memory (ROM), flash memory, solid state drives (SSDs), dynamic random access memory (DRAM) such as synchronous DRAM (SDRAM)), a static memory **1106** (e.g., flash memory, solid state drives (SSDs), static random access memory (SRAM)), and a data storage device **1108**, which communicate with each other via a bus **1110**.

Processing device **1102** represents one or more general-purpose processing devices such as a microprocessor, central processing unit, or the like. More particularly, the processing device **1102** may be a complex instruction set computing (CISC) microprocessor, reduced instruction set computing (RISC) microprocessor, very long instruction word (VLIW) microprocessor, or a processor implementing other instruction sets or processors implementing a combination of instruction sets. The processing device **1402** may also be one or more special-purpose processing devices such as an application specific integrated circuit (ASIC), a system on a chip, a field programmable gate array (FPGA), a digital signal processor (DSP), network processor, or the like. The processing device **1402** is configured to execute instructions for performing any of the operations and steps discussed herein.

The computer system **1100** may further include a network interface device **1112**. The computer system **1100** also may include a video display **1114** (e.g., a liquid crystal display (LCD), a light-emitting diode (LED), an organic light-emitting diode (OLED), a quantum LED, a cathode ray tube (CRT), a shadow mask CRT, an aperture grille CRT, a monochrome CRT), one or more input devices **1116** (e.g., a keyboard and/or a mouse or a gaming-like control), and one or more speakers **1118** (e.g., a speaker). In one illustrative example, the video display **1114** and the input device(s) **1116** may be combined into a single component or device (e.g., an LCD touch screen).

The data storage device **1116** may include a computer-readable medium **1120** on which the instructions **1122** embodying any one or more of the methods, operations, or functions described herein is stored. The instructions **1122** may also reside, completely or at least partially, within the main memory **1104** and/or within the processing device **1102** during execution thereof by the computer system **1100**. As such, the main memory **1104** and the processing device **1102** also constitute computer-readable media. The instructions **1122** may further be transmitted or received over a network via the network interface device **1112**.

While the computer-readable storage medium **1120** is shown in the illustrative examples to be a single medium, the term "computer-readable storage medium" should be taken to include a single medium or multiple media (e.g., a centralized or distributed database, and/or associated caches and servers) that store the one or more sets of instructions. The term "computer-readable storage medium" shall also be taken to include any medium that is capable of storing, encoding or carrying a set of instructions for execution by the machine and that cause the machine to perform any one or more of the methodologies of the present disclosure. The term "computer-readable storage medium" shall accordingly be taken to include, but not be limited to, solid-state memories, optical media, and magnetic media.

Clause 1. A system for positioning one or more sensors on a user, the system comprising:

an apparatus configured to be manipulated by the user to perform an exercise;

user sensors associated with the user;

apparatus sensors associated with the apparatus;

treatment sensors;

a processing device;

a memory communicatively coupled to the processing device and including computer readable instructions, that when executed by the processing device, cause the processing device to:

generate an enhanced environment representative of an environment;

receive, from the apparatus sensors, apparatus data representative of a location of the apparatus in the environment;

generate, from the apparatus data, an apparatus avatar in the enhanced environment;

receive, from the user sensors, user data representative of a location of the user in the environment;

generate, from the user data, a user avatar in the enhanced environment;

receive, from the treatment sensors, treatment data representative of one or more locations of the treatment sensors in the environment;

generate, from the treatment data, treatment sensor avatars in the enhanced environment;

calculate, based on one or more of the apparatus data and the user data, a treatment location for each treatment sensor, wherein the treatment location is associated with an anatomical structure of a user; and

generate, based on the treatment location and treatment data, instruction data representing an instruction for positioning the treatment sensors at the treatment location.

Clause 2. The system of any clause herein, further comprising an interface and wherein the processing device is further configured to:

output, to the interface and based on the environment data, an image representative of the enhanced environment; and

output, to the interface, an image representing the user, apparatus and treatment sensor avatars.

Clause 3. The system of any clause herein, wherein the processing device is further configured to:

generate, based on the treatment location, a treatment location avatar;

output, to the interface, an image representing the treatment location avatar.

Clause 4. The system of any clause herein, wherein the treatment location avatar is one of overlaid on and transposed with a portion of the user avatar.

Clause 5. The system of any clause herein, wherein the processing device is further configured to output, to the interface, the treatment location avatar in a frequency configured to cause the avatar to flash and wherein the frequency of flashing is one or more of:

variable;

static; and

based on the instruction data.

Clause 6. The system of any clause herein, wherein the instruction data represents instruction confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location.

Clause 7. The system of any clause herein, wherein the processing device is further configured to output, to the interface, instructions confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location.

Clause 8. The system of any clause herein, wherein the instructions are one or more of a color-coded indication, audible indication, and a textual message.

Clause 9. The system of any clause herein, wherein the instruction data represents instructions capable of altering the location of the treatment sensor to be one of adjacent to, at, and near the treatment location.

Clause 10. The system of any clause herein, wherein the processing device is further configured to output, to the interface, instructions to move the location of the treatment sensor to the treatment location.

Clause 11. The system of any clause herein, wherein the instructions are defined as one or more of arrows, a color-coded indicator, an audible indication and a textual message.

Clause 12. The system of any clause herein, wherein the processing device is further configured to receive, during a telemedicine-enabled appointment between the user and a healthcare professional, medical instruction data representative of instructions from the healthcare professional.

Clause 13. The system of any clause herein, wherein the processing device is further configured to output, to the interface and based on the medical instruction data, instructions from the healthcare professional.

Clause 14. The system of any clause herein, wherein the medical instruction data refers to a recommended treatment location.

Clause 15. The system of any clause herein, further comprising a medical interface remote from the user and associated with the healthcare professional, and wherein the processing device is further configured to output, to the medical interface, a user response to the medical instruction.

Clause 16. A method for positioning one or more sensors on a user, the method comprising:

generating an enhanced environment associated with an environment;

receiving, from apparatus sensors, apparatus data representative of a location of an apparatus in the environment;

generating, from the apparatus data, an apparatus avatar in the enhanced environment;

receiving, from user sensors, user data representative of a location of the user in the environment;

generating, from the user data, a user avatar in the enhanced environment;

receiving, from treatment sensors, treatment data representative of a location the treatment sensors in the environment;

generating, from the treatment data, treatment sensor avatars in the enhanced environment;

calculating, based on one or more of the environment data, the apparatus data, and the user data, a treatment location for each treatment sensor; and

generating, based on the treatment location and the treatment data, instruction data representative of the treatment sensors relative to the user.

Clause 17. The method of any clause herein, further comprising:

displaying, in an interface and based on the environment data, an image representative of the enhanced environment; and

displaying, with the interface, an image representative of the user, apparatus and treatment sensor avatars.

Clause 18. The method of any clause herein, further comprising:

generating, based on the treatment location, a treatment location avatar;

displaying, with the interface, an image representative of the treatment location avatar.

Clause 19. The method of any clause herein, wherein the treatment location avatar is further defined as being one of overlaid on and transposed with a portion of the user avatar.

Clause 20. The method of any clause herein, further comprising displaying, with the interface, the treatment location avatar in a flashing pattern wherein, the flashing pattern is based on the instruction data.

Clause 21. The method of any clause herein, wherein the instruction data represents instructions confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location.

Clause 22. The method of any clause herein, further comprised of displaying, with the interface, instructions confirming that the location of the treatment sensor is one of adjacent to, at, and near the treatment location.

Clause 23. The method of any clause herein, wherein the instructions are one or more of a color-coded indication, audible indication, and a textual message.

Clause 24. The method of any clause herein, wherein the instruction data represents instructions to alter the location of the treatment sensor to be one of adjacent to, at, and near the treatment location.

Clause 25. The method of any clause herein, further comprising displaying, with the interface, instructions to move the location of the treatment sensor to the treatment location.

Clause 26. The method of any clause herein, wherein the instructions are defined as one or more of arrows, a color-coded indicator, an audible or tactile indication and a textual message.

Clause 27. The method of any clause herein, further comprising receiving, during a telemedicine-enabled appointment between the user and a healthcare professional, medical instruction data representative of instructions from the healthcare professional.

Clause 28. The method of any clause herein, wherein the processing device is further configured to output, to the interface and based on the medical instruction data, instruction from the healthcare professional.

Clause 29. The method of any clause herein, wherein the medical instruction data is representative of a recommended treatment location.

Clause 30. The method of any clause herein, further comprising displaying, with a medical interface remote from the user and associated with the healthcare professional, a user response to the medical instruction.

The above discussion is meant to be illustrative of the principles and various embodiments of the present disclosure. Numerous variations and modifications will become apparent to those skilled in the art once the above disclosure is fully appreciated. It is intended that the following claims be interpreted to embrace all such variations and modifications.

The various aspects, embodiments, implementations, or features of the described embodiments can be used separately or in any combination. The embodiments disclosed herein are modular in nature and can be used in conjunction with or coupled to other embodiments.

Consistent with the above disclosure, the examples of assemblies enumerated in the following clauses are specifically contemplated and are intended as a non-limiting set of examples.

What is claimed is:

1. A computer-implemented system, comprising:

a device configured to be used by a user while performing an exercise session;

an interface configured to present content to the user;

a computing device configured to:

receive data pertaining to a user, wherein the data comprises one or more characteristics of the user;

assign, based on the data, the user to a cohort representing people having one or more similarities to at least some of the one or more characteristics of the user;

generate, based on the user being assigned to the cohort, an exercise plan for the user to perform using the device, wherein the exercise plan is generated by a machine learning model trained to generate exercise plans for cohorts; and

based on the exercise plan, controlling, via the machine learning model, operation of the device by using a transmitted control instruction to change an operating parameter of the device.

2. The computer-implemented system of claim 1, wherein the computing device is configured to transmit the exercise plan for presentation on the interface.

3. The computer-implemented system of claim 1, wherein the machine learning model is trained to generate the exercise plan in real-time or near real-time.

4. The computer-implemented system of claim 1, wherein the computing device is configured to provide instructions on via the interface, wherein the visual instructions guide the user to place a sensing device on a portion of the user's body.

5. The computer-implemented system of claim 4, wherein the sensing device comprises a goniometer, a wearable device, or both.

6. The computer-implemented system of claim 1, wherein the device comprises one of a mirror, a reflective surface, a projective capability, or some combination thereof.

7. The computer-implemented system of claim 1, wherein the device is a treadmill.

8. The computer-implemented system of claim 1, wherein the device is an electromechanical spin-wheel.

9. The computer-implemented system of claim 1, wherein the device is an electromechanical bicycle.

10. The computer-implemented system of claim 1, wherein the user data comprises information pertaining to an electronic medical record of the user.

11. A method for assigning a user to a cohort based on one or more characteristics of the user, the method comprising, at a server device:

receiving data pertaining to the user, wherein the data comprises the one or more characteristics of the user;

assigning, based on the data, the user to a cohort representing people having similarities to at least some of the one or more characteristics of the user;

generating, based on the user being assigned to the cohort, an exercise plan for the user to perform using a device, wherein the exercise plan is generated by a machine learning model trained to generate exercise plans for cohorts; and

based on the exercise plan, controlling, via the machine learning model, operation of the device by using a transmitted control instruction to change an operating parameter of the device.

12. The method of claim 11, further comprising transmitting the exercise plan for presentation as the content on an interface.

13. The method of claim 11, wherein the machine learning model is trained to generate the exercise plan in real-time or near real-time.

14. The method of claim 11, further comprising providing visual instructions on an interface, wherein the visual instructions guide the user to place a sensing device on a portion of a body of the user.

15. The method of claim 14, wherein the sensing device comprises a goniometer, a wearable device, or both.

16. The method of claim 11, wherein the device comprises one of a mirror, a reflective surface, a projective capability, or some combination thereof.

17. The method of claim 11, wherein the device is a treadmill.

18. The method of claim 11, wherein the device is an electromechanical spinwheel.

19. The method of claim 11, wherein the device is an electromechanical bicycle.

20. The method of claim 11, wherein the user data comprises information pertaining to an electronic medical record of the user.

21. A tangible, non-transitory computer-readable medium storing instructions that, when executed, cause a processing device to:

receive data pertaining to a user, wherein the data comprises one or more characteristics of the user;

assign, based on the data, the user to a cohort representing people having similarities to at least some of the one or more characteristics of the user;

generate, based on the user being assigned to the cohort, an exercise plan for the user to perform using a device, wherein the exercise plan is generated by a machine learning model trained to generate exercise plans for cohorts; and

based on the exercise plan, controlling, via the machine learning model, operation of the device by using a transmitted control instruction to change an operating parameter of the device.

22. The computer-readable medium of claim 21, wherein the processing device is configured to transmit the exercise plan for presentation as the content on an interface.

23. The computer-readable medium of claim 21, wherein the machine learning model is trained to generate the exercise plan in real-time or near real-time.

24. The computer-readable medium of claim 21, wherein the processing device is configured to provide visual instructions on an interface, wherein the visual instructions guide the user to place a sensing device on a portion of a body of the user.

25. The computer-readable medium of claim 24, wherein the sensing device comprises a goniometer, a wearable device, or both.

26. The computer-readable medium of claim 21, wherein the device comprises one of a mirror, a reflective surface, a projective capability, or some combination thereof.

27. The computer-readable medium of claim **21**, wherein the device is a treadmill.

28. The computer-readable medium of claim **21**, wherein the device is an electromechanical spin-wheel.

29. The computer-readable medium of claim **21**, wherein the processing device:

receive second data pertaining to the user, wherein the data comprises one or more second characteristics of the user;

reassign, based on the second data, the user to a second cohort representing second people having one or more second similarities to at least some of the one or more second characteristics of the user; and

generate, based on the user being assigned to the second cohort, a second exercise plan for the user to perform using the device, wherein the second exercise plan is generated by a machine learning model trained to generate the exercise plans for the cohorts.

30. An apparatus, comprising:

a memory device storing instructions; and

a processing device communicatively coupled to the memory device, wherein the processing device is configured to execute the instructions to:

receive data pertaining to a user, wherein the data comprises one or more characteristics of the user;

assign, based on the data, the user to a cohort representing people having similarities to at least some of the one or more characteristics of the user;

generate, based on the user being assigned to the cohort, an exercise plan for the user to perform using a device, wherein the exercise plan is generated by a machine learning model trained to generate exercise plans for cohorts; and

based on the exercise plan, controlling, via the machine learning model, operation of the device by using a transmitted control instruction to change an operating parameter of the device.

* * * * *